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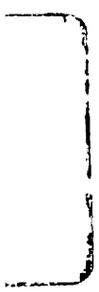

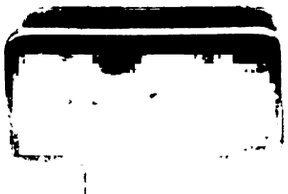

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RECORDS

OF THE

SURVEY OF INDIA

Volume XVI

(Supplementary to General Report 1920-21)

ANNUAL REPORTS OF

PARTIES AND OFFICES

1920-21.

PREPARED UNDER THE DIRECTION OF

Colonel C. H. D. RYDER, C.B., C.I.E., D.S.O., R.E.

Surveyor General of India.

DEHRA DÛN
PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY
1922

Price Four Rupees or Eight Shillings.

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MAJOR JAMES RENNELL.
BENGAL ENGINEERS.
SURVEYOR GENERAL OF BENGAL 1767-1776.

Survey of India Offices. Calcutta. 1922.

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Major James Rennell,
Bengal Engineers,
Surveyor & Geographer.

Born 3rd December 1742. Buried in Westminster Abbey 6th April 1830.

Fellow of the Royal Society 1781. Copley medal of the Royal Society 1791.. Member of the Institute of France; of the Imperial Academy of St. Petersburg; and of the Royal Society of Gottingen. Instrumental in the forming of the African Society, whilst the Royal Geographical Society was his "Successor and Executor".

Served in the Royal Navy 1756—1763; as a Surveyor in Bengal 1764—1766; and as Surveyor General 1767—1776.

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2. Surveys executed after 1905 are classed as "MODERN", those PRIOR to that date are classed as "OLD".

3. Maps are printed in two styles or editions *viz.*, LAYERED and POLITICAL:—

(*a*) The LAYERED edition represents a map printed in colours with graduated layer tints of colour to show altitudes, and, shading to emphasize the hills. This edition gives prominence to the physical features.

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(*c*) INTERNATIONAL MAP OF INDIA, scale 1:1,000,000 or nearly 1 inch = 16 miles, in LAYERED edition (without shading of hills), size 30 inches × 26 inches, price Re. 1-0 per copy.

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(*c*) SCALE 1 INCH = 4 MILES, in the LAYERED and POLITICAL editions, size 24 × 19 inches, price Re. 1-8 per copy, and from old surveys as PROVISIONAL issues, price Re. 1 per copy.

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(III) GENERAL MAPS which include:—

(*a*) GENERAL MAPS OF INDIA, scale 1 inch = 32 miles, in sets of 12 sheets, each sheet 25 × 32 inches, in LAYERED and POLITICAL (without hills) editions, price Rs. 12 per set, and on scale 1 inch =64 miles, POLITICAL edition only, size about 3½ feet square, at Rs. 6 the copy. Also various maps of India on the same and smaller scales and miscellaneous special maps illustrating Railways, &c.

(*b*) PROVINCIAL MAPS, on scales 1 inch = 16 miles and 1 inch =32 miles.

(*c*) DISTRICT MAPS, on scales 1 inch = 4 miles and 1 inch = 8 miles.

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PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(Vide Index Map No. 1)

Summary.—This circle was under the superintendence of Lieutenant-Colonel H.L. Crosthwait, C. I. E., R. E., up to the 13th December 1920 and of Lieutenant-Colonel H. Wood, R.E., from the 14th December to the close of the survey year. It comprised Nos. 1,2,3,4 Topographical Parties, No. 3 Drawing Office, Sind-Sāgar Party and No. 22 (Riverain) Party.

During the year Nos. 1,2,3 Parties completed 14,411 square miles of detail survey on the quarter-inch, half-inch, one-inch, two-inch and four-inch scales, besides 13½ square miles on larger scales. In connection with the survey on the smaller scales an area of 3,680 square miles was triangulated and 593·35 square miles was traversed.

The detail survey consisted of:—

159	square	miles	of quarter-inch revision survey
1,524	„	„	„ half-inch original survey
2,365	„	„	„ half-inch revision survey
419	„	„	„ one-inch original survey
6,870	„	„	„ one-inch revision survey
1,698	„	„	„ one-inch re-survey
1,247	„	„	„ two-inch original survey
134	„	„	„ four-inch revision survey.

The Sind-Sāgar Party and No. 22 (Riverain) Party continued special work in the Punjab for the Local Government. The former carried out rectangulation work in the Sind-Sāgar Doāb and Sutlej Valley, and the latter, the usual riverain surveys in the Punjab.

No. 4 Party was kept in abeyance as a topographical unit.

No. 1 PARTY (PUNJAB, NORTH-WEST FRONTIER PROVINCE AND UNITED PROVINCES).

By P. A. T. Kenny, M.B.E.

The country surveyed, with the exception of a small tract in the Kohāt district of the North-West Frontier Province, lies wholly in the Punjab and comprises parts of the districts of Kāngra and Simla, and the Chamba, Mandi, Suket, Patiāla and Simla Hill States. The area is traversed by the Chenāb, Rāvi, Beās and Sutlej rivers and consists for the most part of high wooded hills and snowy ranges of the middle and outer Himālaya ranges, and partly of low, undulating, highly cultivated hills of Siwālik formation. The altitude ranges from 950 feet on the Rāvi river to 21,000 feet. This necessitated the party working on the hills up to 10,000 feet during the winter months; and on the higher ranges in the Pāngī tahsil of Chamba State and the Kulū sub-division of Kāngra district during the summer, when the snows had melted and rendered the higher peaks and glaciers accessible to the planetabler. The heavy monsoon rains of 1921, and the difficulties of transport in the remoter valleys, seriously retarded the progress of the survey, and protracted the field season to the end of September 1921.

Personnel.

Class I Officer.

Major H.T. Morshead, D.S.O., R. E., in charge up to 18th March 1921.

Class II Officers.

Mr. P. A. T. Kenny, M. B. E., in charge from 19th March 1921.
Major C. H. Tresham.
Mr. R.C. Hanson.
„ A. J. A. Drake, D. C. M., from 25th October 1920.
„ H.T. Hughes, from 27th April 1921.

Upper Subordinate Service.

Mr. Jamna Prasad, R.S., up to 28th March 1921.
„ Muhammad Husain Khan, K. S.
„ Vidya Dhar Chopra, from 1st May 1921.
„ Afraz Gul Khan.
„ Muhammad Khan.
„ Jit Singh Rawat.
„ Sijawal Khan.

Lower Subordinate Service.

44 Surveyors, etc.

The headquarters of the party opened at Dehra Dun on 25th October 1920, and re-opened at Mussoorie on 29th March 1921.

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The health of the party was uniformly good; two surveyors, however, died from natural causes at their homes while on leave.

Plane-tabling.—The distribution of the party for carrying out the field programme was as follows:—

No. 1 Camp, under Mr. P.A.T. Kenny, up to the end of February 1921, and then under Mr. R.C. Hanson, took up the one-inch revision survey of sheets 52 D/16, 53 A/11.15.16, 53 E/1.2, and parts of sheets 52 H/3.4, the half-inch revision of parts of sheets 52 H/3.4.7.8, 53 E/5.6 9.10.13, the quarter-inch revision of parts of sheets 52 H/12.16, the one-inch original survey of parts of 52 D/13.14.15, 52 H/2.3 and the half-inch original survey of the remaining parts of 52 H/2.3.7.8.11 in the Mandī, Suket and Simla Hill States of Bilāspur, Bashahr, Nālāgarh, Bāghal, Mailog, Māngal and Kunihār, the Kulū subdivision of Kāngra district and small portions of Simla district and Patiāla State.

No. 2 Camp, under Mr. R.C. Hanson up to the middle of February 1921, and then under Mr. A.J.A. Drake, took up the one-inch revision of sheets 43 P/16, 52 D/2.5.6.8.9.10.11 and parts of 52 C/8.12.16 and D/1.13.14.15 and the half-inch revision of sheets 52 D/4.12 in the Kāngra district and Chamba State.

Sheets 52 D/3.7 were also revised, in the first instance, on the half-inch and subsequently on the one-inch scale.

These two camps also undertook the hill training of 18 pupil surveyors and the services of Messrs. Muhammad Khan, and Sijawal Khan and Surveyor Lalbir Singh were utilised for this purpose under the two camp officers. Only one of these pupils turned out a failure and was discharged on his return from the field.

A third camp was formed and placed under Mr. Jit Singh Rawat, assisted by two surveyors, to take up the eight-inch survey of a proposed cantonment in sheet 38 K/11 in the neighbourhood of Doāba Railway station in the Kohāt district of the N.W. Frontier Province. The area consisted of a sloping plain or dāmān at 3,000 feet above sea level, partly under cultivation, and partly waste land, covered with scattered bushes and cut up by numerous dry watercourses. The camp completed the 13½ square miles in 3 months and returned to field headquarters early in March 1921. The whole area was worked from an entrenched camp at the south-west corner of the area, which entailed individual surveyors walking long distances daily to reach their ground. One of them was waylaid by hostile tribesmen on his return to camp at the end of a day's work and the 3 sepoys of his escort and a khalasi were shot dead. The surveyor was, however, able to save his plane-table section, but lost some of his instruments.

The total area surveyed during the combined winter and summer field seasons amounted to 8,413½ square miles distributed as follows:—

One-inch revision survey of sheets 43 P/16, 52 D/2.3.5.6.7.8.9.10.11.16, 53 A/11.15.16, 53 E/1.2 and parts of 52 C/8.12.16, D/1.13.14.15 and H/3.4; half-inch revision survey of sheets 52 D/3.4.7.12 and parts of 52 H/3.4.7.8 and 53 E/5.6.9.10.13; quarter-inch revision survey of parts of sheets 52 H/12.16, one-inch original survey of parts of 52 D/13.14.15 and H/2.3, half-inch original survey of parts of sheets 52 H/2.3.7.8.11, eight-inch original military survey in 38 K/11.

The data used was old four-inch and two-inch triangulation executed prior to 1905, computed in rectangular co-ordinates and was ample. Great labour, however, was entailed in searching through a very large number of computation volumes for this, as none of it appears in the published triangulation pamphlets. The work occupied the services of a Class II officer and 3 to 4 surveyors during 3 months of the previous recess. The fact that the computations were based on more than one origin added to the labour.

Another Class II officer was employed during 4 months of the previous recess in preparing plane-table sections for the field season's work; this entailed the thickening up of the line work and the 250 and 500 foot contours on the large scale published sheets, as well as the pasting up of mosaics of the reductions to form standard sheets. The resulting blue print reductions were not always legible and the surveyors concerned spent a few days before commencing work on their boards in inking them up in blue with the aid of the original large scale maps.

In addition to the three camps in the field, a large drawing section, supervised by the officer in charge and Messrs. Drake and Jamna Prasad, was retained in field headquarters to deal with the heavy arrears of the previous recess season's fair-mapping.

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As the two camps did not return to recess headquarters till the end of September and the early part of October, it was only possible to work out the cost-rates for the different classes of survey and not for each scale (vide Table III).

Triangulation.—Major C. H. Tresham triangulated in advance an area of 2,400 square miles, in the Tehrī State of the United Provinces falling in sheets 53 I/4. 8. 12, 53 J/1. 5. 7. 9. 10. 11. 13. 14. 15. A great part of the country is above the tree line, but the lower slopes of the inner, and the northern slopes of the outer ranges are generally thickly wooded with oak, conifers, spruce and rhododendron. The chief rivers are the Tons, Jumna and the Bhāgīrathi branch of the Ganges—all these and most of their tributaries flow in deep narrow gorges. The well-known peaks of Srikanta (20, 120), Sargaroin or Sarganahin (20, 480), Bandarpūnch (20, 720), Jaonli (21, 760) and Tharlasagar (22, 610), as well as the two great Hindu places of pilgrimage, Gangotrī and Jamnotrī also fall in the area. The highest point reached by the observer was 19,600 feet.

Recess Duties.—The fair-mapping of the current field season's out-turn was complicated by the fact that the survey of a large number of the sheets was not completed till late in 1921 and also by the legacy of arrears left over from the previous recess. These arrears included the difficult and intricate twenty-four-inch survey of Mussoorie (3 sheets), the eight-inch guide map of Mussoorie and Landour, the completion of some of the one-inch and half-inch sheets of the late Wazīristān party, as well as the party's 1919-20 field programme. Owing to the fact that the bulk of the best surveyors of the party, as well as two experienced Class II officers, were in the field in the two camps for the best part of a year, a great deal of the fair-mapping was executed by pupils who required constant and rigorous supervision, which was not always available.

Mr. Kenny during March 1921, supervised the completion of the Wazīristān mapping, and later took over charge of the party, when Major Morshead left to join the Mount Everest expedition.

Major Tresham supervised the computation of his triangulation, the fair-mapping of sheets 52 D/1.7 and assisted in the final examination of some of the arrears sheets.

Mr. Drake, assisted by Mr. Jamna Prasad, supervised the fair-mapping of the 1919-20 arrears up to the middle of February 1921, when he was relieved by Mr. Hanson, who carried on till early in March, when he returned to the field.

Mr. H. T. Hughes, supervised the fair-mapping of sheets 43 P/16, 53 A/11.15.16 and the completion of the Mussoorie and Landour eight-inch guide map. His section consisted almost entirely of pupil surveyors and draftsmen sent to the party for instruction in drawing.

Mr. Afraz Gul Khan, on return from leave in April supervised part of the arrears of mapping up to August, when Mr. Muhammad Husain Khan, K. S., returned from long leave and took over his section.

Mr. Vidya Dhar Chopra, on return from leave in August assisted Major Tresham in the computations of the latter's triangulation.

Mr. Jit Singh Rawat, on return to field headquarters in March 1921, supervised the tracing of his eight-inch military survey and also part of the mapping of arrears, as well as that of sheet 52 D/11 of the current field season's work.

Owing to the heavy arrears of the previous recess season's work occupying most of the available draftsmen and surveyors, and also to the fact that a number of the best surveyors were in the field up to the end of September 1921, the mapping of only 7 of the one-inch sheets of the 1920-21 field programme could be taken up during the recess. The mapping of the remaining sheets will be carried out during the winter of 1921-22 and the summer of 1922.

During the recess, the fair-mapping of the three twenty-four-inch Mussoorie sheets was completed, as well as that of fourteen one-inch and two half-inch sheets.

Inspection.—The party was inspected by the Surveyor General and Superintendent Northern Circle at field headquarters in March 1921, and twice during recess in April and September 1921. The Superintendent Northern Circle also paid weekly visits to the party throughout the recess.

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NO. 2 PARTY (CENTRAL INDIA, DELHI PROVINCE, RĀJPUTĀNA AND UNITED PROVINCES).

By Bt. Lt.-Colonel S. W. S. Hamilton, D. S. O., R. E.

The normal topographical programme of the party was continued.

Personnel.

Class I Officer.

Bt.-Lt.-Col. S. W. S. Hamilton, D. S. O., R. E.

Class II Officers.

Mr. C. O. Picard.
„ Duni Chand Puri.
„ Prafulla Kumar Ghosh, B. Sc. (on probation).
„ T. O. Threlfall (on probation).

Upper Subordinate Service.

Mr. Imam Din.
„ Muhammad Husain.
„ Lakshmi Dutt Joshi.
„ Daulat Ram Vohra.
„ Narsingh Das Joshi (on probation).

Lower Subordinate Service.

48 Surveyors, etc.

(*a*) Original survey on the half-inch scale of sheet 54 E/SW.

(*b*) Re-survey on the one-inch scale of sheets 54 E/11.15 and 54 I/2.6.9.13.

(*c*) Revision survey on the one-inch scale of sheets 54 E/10 and 54 I/1.5.10.14.

(*d*) Revision survey on the four-inch scale of Delhi and vicinity, including Imperial Delhi and Delhi New Cantonment.

(*e*) Traversing for original survey on the one-inch scale in parts of sheets 54 J/1.2.5.6.9.

(*f*) Traversing for original survey on the sixty-four-inch scale in Allahābād city.

The country surveyed on the one-inch scale consisted of cultivated plains, open and easy, except in a few places where trees were numerous. There was a good deal of broken ground and occasionally high grass along the banks of the Jumna river, while the banks of the Ganges river were much intersected.

The area surveyed on the half-inch scale also consisted of open cultivated plains and included occasional isolated low rocky hills similar in structure to the "Ridge" bordering on the west and south-west of Imperial Delhi.

The head-quarters opened in the field at Agra on the 29th October 1920 and re-opened in recess at Mussoorie on the 9th May 1921. The health of the party was excellent.

Plane-tabling.—As in the previous season, all first year soldier surveyors and pupil surveyors in the circle, numbering 4 and 18 respectively, were attached to No. 2 Party by the Superintendent for training, in addition to which there were also two Class II and one Upper Subordinate officers on probation. The country lent itself well for training purposes, though it was not possible to give any real instruction in contouring and the depiction of hill features. This latter will be given in the second year of training in other parties working in hilly areas.

The party was divided into 5 camps as given in the table below :—

No. of camps.	Name of camp officer.	Camp head-quarters.	No. of surveyors.	No. of soldier surveyors, pupils and proba-tioners.	No. of sheets.	Scale and class of survey.
1	Mr. C. O. Picard	Bharatpur	4	...	54 E/SW.	Half-inch original
2	Mr. D. C. Puri	Muttra	2	10	54 E/10.11.15	One-inch revision and re-survey
3	Mr. Imam Din	Hāthras	4	9	54 I/1.2.5.6	do.
4	Mr. L. D. Joshi	Kāsganj	5	6	54 I/9. 10. 13.14	do.
5	Mr. C. O. Picard	Delhi	4	...	Nos. 1, 2, 3, 4 Delhi	Four-inch revision
	Totals ...	...	19	25	16	

Mr. D. R. Vohra held charge of No. 1 Camp while No. 5 Camp was directly under the officer in charge of the party until Mr. Picard joined from sick leave at the end of January.

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Revision survey was carried out by trained surveyors, while re-survey was done by soldier surveyors, pupils and probationers, this class of work having been specially arranged for their training in lieu of revision survey. The work was based on old revenue traverse data. Plot charts for each one-inch sheet having been made in recess, a convenient area, not too difficult but containing as much variation of detail as possible, was selected for each camp. This area with its graticules, traversed trijunctions, scales, lists, etc., etc., was plotted from the traverse plot chart on to a bristol board in recess, one for each man under training. On arrival at party head-quarters, this arrangement enabled each camp to be ready to proceed to its area within 3 days. Each camp officer then spent from a month to 6 weeks within the area selected, in individual training of his men according to their capabilities, after which and when their training had been approved by the officer in charge of the party, men were given separate and independent plane-table sections which had meanwhile been prepared and were in readiness as required. Each camp officer with men under training was allowed one first class surveyor to assist him until his men could work independently and without continual supervision, this period varying from 6 weeks to 2 months.

The work in sheet 54 E/SW. was based on old traverse data supplemented during the previous season, while that of Delhi and Vicinity was based on the triangulation specially executed for this survey in 1916-17 and on the boundary traverse executed in 1915-16, the work being done on vandyked blue prints of the previous last revision. This is the third biennial revision of the latter and, as it is probable, it will be the last to be undertaken for some time. Except in the detail in the old cantonment and in the contouring of the two northern sheets, Nos. 1 and 2, only very minor changes were disclosed other than those due to building operations. The rigorous contouring of sheet 54 $E/_{12}$ on the one-inch scale which the experimental æro-survey party was unable to undertake in 1919-20 was completed by Mr. D. R. Vohra after he had handed over No. 1 Camp to Mr. C. O. Picard. A line of traverse heights joining two trigonometrical stations close to the north-western and southern margins on which to base the contouring was run early in the season.

In order to give a greater usefulness to the published sheets, the heights along main canals have been obtained from the various executive engineers concerned and selected values have been inserted on the fair maps in such areas in the plains where no other information was available, a note to this effect being entered on the plane-table sections. Where possible, these have been compared with levelled bench-marks and with heights obtained from traverse work done by the party and have been found not to vary by more than two to three feet.

The cost-rate for half-inch original survey, Rs. 12·1 per square mile, is high, due to a small detached camp of poorly qualified surveyors having to bear a large proportion of the pay of Mr. Picard, for whom it was inadvisable to alter arrangements at the period of the field season that he returned from sick leave.

No *triangulation* was carried out by the party during the year.

Traversing.—The country traversed in sheets $54J/_{1.2.5.6.9}$ for plane-tabling on the one-inch scale was largely along the banks of the Chambal river consisting of much broken and intersected ground where the subtense bar frequently had to be used. The traverse was executed in order to provide points for plane-tablers and considerable difficulty was experienced in the more open ground in getting the traversers, who had no knowledge of plane-tabling, to understand this and that long lengths were required between stations, from 40 to 60 chains being laid down as the average, and that short lengths were a waste of time. These two points have somewhat affected the cost-rate. The work was in charge of Mr. Muhammad Husain with an establishment of 5 traversers and 5 computers. Computations were carried out *pari passu* with the traverse. On completion the traverse camp was transferred to Allahābād where it commenced the traverse of Allahābād city for detail survey on the sixty-four-inch scale for the Allahābād Improvement Trust. This traverse was undertaken at the special request of the Governor of the United Provinces and will be completed during the ensuing field season 1921-22 (*see also Part III-Special Report*).

Two of the computers remained at head-quarters preparing traverse plot charts on the one-inch scale for the ensuing field season, while one of the traversers proceeded on leave.

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Fair-mapping, arrears.—Half-inch sheet 54 A/SW., the fair-mapping of which was practically completed, was taken to field head-quarters for final examination and was submitted for publication in February 1921. Two other half-inch sheets, viz. 53 D/NW. and D/NE., were also taken to the field. Fair-mapping was done in a tent under difficult conditions of wind and dust. The sheets got very dirty, work was very slow being in charge of an officer in addition to his other duties, which did not allow time for sufficient supervision. The arrangement was not a success.

Recess Duties.—(*a*). For the purpose of fair-mapping the party was divided into three sections as given in the table below :—

No. of section.	Name of Section officer.	No. of draftsmen etc.	No. of sheets.	Scale of fair-drawing.
1	Mr. C. O. Picard	8	53 D/NW. NE. 54 E/NW. NE. SW.	¾-inch
2	Mr. D. C. Puri	7	54 E/10. 11. 15 54 I/9. 13 Nos. 1. 2. 3. 4 Delhi	1½-inch 4-inch
3	Mr. Imam Din	8	54 E/12 and 54 I/1. 2. 5. 6. 10. 14	1½-inch

One-inch sheets 54 E/10. 11. 12. 15 and 54 I/1. 2. 5. 6 and half-inch sheet 53 D/NW. have been submitted for publication in September 1921 and the remainder, one-inch, half-inch, and four-inch Delhi with the exception of sheet 54 E/NE. of which sheet 54 E/10 was only surveyed in 1920-21, will be submitted before the party leaves for the field. No. 2 Party will thus have no arrears of fair-mapping. Sheet 54 E/NE. will be submitted during recess 1922. The out-line of 2 sheets, viz :— 54 L/9. 10 has been drawn on contract overtime on the system adopted in No. 3 Party last recess. An estimate is made of the number of hours required and the draftsman, who must have first class qualifications, is then given the sheet to draw entirely out of office hours, being paid his overtime on completion. The proviso was however added that any corrections must be carried out by him as overtime without payment. This innovation has proved very successful, as has also the system of overtime generally which is a valuable reform in the department, and of great assistance to officers in charge of parties. The amount expended on overtime payments during recess will total Rs. 763.

A section was also maintained for the training of soldier surveyors and pupils. Nine soldier surveyors joined the party for their first year of training on the first June 1921.

Mr. L. D. Joshi proceeded on sick leave early in June and the services of Mr. D. R. Vohra were lent to No. 3 Party for the greater part of the recess.

(*b*). A section composed of 3 traversers and 5 computers under Mr. Muhammad Husain, and, after he proceeded on furlough in August, under Mr. P. K. Ghosh, has been employed throughout the recess in computation and preparation of traverse plot charts from old revenue data and from the traverse work of the past season, required for next season's survey on the one-inch scale. The computation of such of the traverse of Allahābād city as was finished has also been completed and 78 traverse plot charts for detail survey on the sixty-four-inch scale drawn and handed over to the Chief Engineer, Allahābād Improvement Trust. Other miscellaneous work has consisted in keeping the party records etc., up to date, preparation of bristol boards for training of next year's pupils, preparation of index maps, field progress charts, triangulation charts etc., etc.

During the recess all data, maps etc., required for the next four years' programme have been obtained and arranged and stored in the office.

Inspections.—The party was inspected once by the Surveyor General and on numerous occasions by the Superintendent, Northern Circle.

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No. 3 PARTY (UNITED PROVINCES).

By Captain L. H. Jackson, I. A.

The area under survey on the two-inch scale lay in Paurī Tahsīl of Garhwāl district and in the Kumaun hills, and consisted for the most part of densely wooded hills and cultivated valleys. The area under survey on the one-inch scale lay in the Tarai and Bhābar and Nepāl, and consisted of densely wooded hills and plains covered with thick elephant grass and dense forests.

Personnel.

Class I Officers.

Bt.-Major C. G. Lewis, R.E., in charge up to 25th October 1920.

Captain L. H. Jackson, I. A., in charge from 26th October 1920.

Captain E. A. Glennie, D. S. O., R. E. (on probation).

Class II Officers.

Mr. E. B. West from 1st November 1920.

„ L. Williams.

„ J. H. Johnson.

„ G. E. R. Cooper, to 30th June 1921.

Upper Subordinate Service.

Mr. Laltan Khan I. .S. M. from 25th November 1920.

Lower Subordinate Service.

44 Surveyors, etc.

On the 15th November the party arrived at its field headquarters at Bareilly, whence the several camps proceeded immediately to their respective areas. The projection and plotting of plane-tables had been carried out previously in Mussoorie. Field work was completed by the 5th May. Although cholera, smallpox, and influenza were prevalent during the latter half of the field season, the health of the party was good, the average amount of sickness per surveyor being approximately one day in two months. Surveyor Muhammad Yakub Khan died while on leave at his home. There were two deaths from cholera among menials out of four cases, and one khalasi of the triangulation squad was killed by a falling log.

Plane-tabling.—The programme comprised the survey of sheets 53 J/16, 53 N/4 (part), 8 (part), 53 O/12.14.15.16, 62 C/3 S. 7S (part). 4. 8N (part).

The greater part of the area consisted of reserved forests, a survey of which was required on the two-inch scale. The forests were distributed throughout the whole area and the survey of the intervening non-forest lands on the one-inch scale would have entailed numerous un-economical changes of scale. Consequently, the whole area was surveyed on the two-inch scale, with the exception of 670 square miles in 53 O/12.16 and 62 C/4 of which old four-inch forest maps were in existence, and which were consequently surveyed on the one-inch scale.

The work was distributed in four camps as follows:—

Captain Glennie—62 C/3S. 7S (part).

Mr. L. Williams—53 O/15. 16 (part), 62 C/4. 8 (part).

„ J.H. Johnson—53 O/12.14.16 (part).

„ E.B. West—53 J/16, N/4 (part). 8 (part).

The chief feature of the work was the necessity for surveying the intricate net-work of forest boundaries, both exterior, and interior, down to compartment boundaries. Each individual pillar had to be shown and its position compared with the gazetted boundary notification. When serious discrepancies occurred the notified descriptions were amended and sent to the Forest Department for acceptance and rectification.

Four soldier surveyors completed their first period of training at the close of the field season and three returned to their units, one being retained for further training.

Triangulation.—The programme of triangulation comprised sheets 53 N/8 (part). 12.16, 62 B/4. 8. 12. 62 C/1 (part). 5. 9 (part) for survey on the two-inch scale. The work was executed by Mr. Cooper, who was, however, prevented by snow from crossing the range of hills from 12,000 to 20,000 feet high, which runs through 62 B/8, C/5 and C/9. He was therefore unable to complete the triangulation of 62 B/8.12, C/5 (North) and C/9 (North). The work was considerably impeded by snow from January onwards. The most suitable month for triangulating this area would be October.

Traversing of 44·2 linear miles was carried out in the Nepāl portion of 62 C/4. The traverse would not prove and was rejected.

Recess Duties.—(*a*) The fair-mapping was distributed in three sections.

No. 1 under Mr. West, sheets 53 J/16 N&S, 53 N/4 N & S, 53 N/8 S, 53 O/16 N, 53 O/16, 62 C/3 S, 62 C/7 S.

No. 2 under Mr. Williams, sheets 53 O/15 N&S, 62 C/4 N, 62 C/8 N. 62 C/4.

No. 3 under Mr. Johnson, sheets 53 O/14 N & S. 53 O/12 N, 53 O/12.

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The whole of the mapping was done on the two-inch scale for publication on the same scale in a combined public and forest edition, except sheets 53 O/12, O/16, and 62 C/4, which were mapped on the one and a half-inch scale for publication on the one-inch scale. The northern halves of these sheets were also mapped on the two-inch scale for publication on the same scale. Sheets 53 N/4 N and 53 N/8 S were not taken in hand as more than half the areas of these sheets still remain to be surveyed. The fair-mapping of sheet 53 N/4 S was commenced, but was not completed as a small portion still remains to be surveyed.

In addition to current mapping, eight arrears sheets, viz. 53 O/9 N & S, 53 O/10 N & S, 53 O/11 N & S, and 53 O/13 N & S, remained over from last season. Of these, 53 O/13 N & S had been completed and only required final scrutiny by the officer in charge of the party. As regards 53 O/9 N & S and O/10 N & S the drawing and about 50 per cent of the typing only had been completed. The fair-mapping of 53 O/11 N & S had not been commenced. All these sheets, with the exception of 53 O/13 N & S, were distributed among the three sections, and will be submitted before the end of recess.

Of the current mapping it is anticipated that sheets 53 J/16 N & S, 53 O/14 N & S, 53 O/12 N, 53 O/12, and 62 C/7 S will be submitted by the end of recess. The delay in submission of the remainder is due to (1) the fact that the sections employed on them have had only a four months recess, (2) the necessity of sending mosaics of certain sheets, viz. 53 O/15 N & S, 62 C/4 N and 62 C/4 to Calcutta for reproduction. Sheet 62 C/8 N is being held up pending receipt of necessary information from the Nepāl Darbār.

In order to cope with the mapping, considerable use was made of overtime work. 12 surveyors, including 2 draftsmen from No. 3 Drawing Office, were placed on the overtime list, and it is estimated that approximately 4½ sheets on the two-inch scale were completed during the extra time. The sheets, both outline and hill, were given out as contract work. This method proved advantageous as the sheets were always available for *pari passu* examination by the section officer during office hours. Unfortunately, owing to lack of funds, overtime work had to be stopped from the 4th August 1921. If it had been possible to continue overtime work up to the end of recess, all the current as well as arrears sheets would have been submitted for publication.

(*b*) The computations of triangulation were completed in recess.

Inspections.—The party was inspected once by the Surveyor General in recess, and once in the field, and weekly in recess, by the Superintendent, Northern Circle.

No. 4 PARTY (UNITED PROVINCES).

By M.C. Petters.

The topographical work of the party remained in abeyance, the officer in charge being employed on the completion of the fair-mapping of two-inch sheets left by No. 3 Party on taking the field, and the final examination and submission for publication of two-inch sheets 53 O/5 N, 53 O/5 S and 53 O/6 N belonging to the same party. He also took over the instruction of 12 pupils attached to the Northern Circle Office from the end of May 1921.

PERSONNEL.

Class I Officers.

Captain L. H. Jackson, I. A., in charge up to 4th November 1920.

Mr. J. A. Freeman, in charge from 5th November to 14th December 1920.

„ H. H. B. Hanby, in charge from 15th December 1920 to 30th January 1921.

„ M. C. Petters, in charge from 31st January 1921.

Lower Subordinate Service.

18 Surveyors, etc.

The surveyors of the party were chiefly employed under the Officer in charge No. 3 Drawing Office, on fair-mapping, the preparation of colour guides and other miscellaneous duties.

Inspections.—The party was inspected by the Surveyor General and on several occasions by the Superintendent of the Circle during recess.

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SIND-SĀGAR PARTY (PUNJAB).

By Major R. Foster, I. A.

The party was employed on rectangular demarcation in connection with the Punjab Government's Sind-Sāgar and Sutlej Valley Canal and Colonization Projects consisting of:—

(a). In the Sind-Sāgar area sub-demarcation of 4,000-acre rectangles into 100-acre rectangles in the area falling in sheets 39 M/11.12.15.16 and 44 A/3.4.

(b). In the Sutlej Valley area.

(1) Triangulation, for location of the corners of 2,400-acre rectangles, in parts of sheets 39 O/5.6.9.10.13.14 and 44 C/1.2.6.

(2) Location of the corners of 2,400-acre rectangles from traversed point in parts of sheets 39 N/16, 39 O/9.10.13 and 44 B/4.8 and 44 C/1.5.

(3) Sub-demarcation of 2,400-acre rectangles into 25-acre rectangles in the area falling in sheets 39 N/16, 39 O/9.10.13 and 44 B/4 and 44 C/1.

PERSONNEL.

Class I Officer.

Major R. Foster, I. A., in charge from 3rd November 1920 afternoon.

Class II Officers.

Mr. Dhani Ram Verma, in charge up to 3rd November 1920 forenoon.
" J. C. C. Lears.
" Maya Das Puri, Rai Sahib, from 1st April 1921.
" D. N. Banerjee, from 19th October 1920.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
" Nabidad Khan.
" Amrit Ram from 6th October 1920.

Lower Subordinate Service.

10 Surveyors, etc.
27 Local Revenue Staff.

The Sind-Sāgar Doāb is the tract situated between the Indus and Jhelum and Chenāb rivers and includes parts of Miānwāli, Shāhpur, Jhang and Muzaffargarh districts in the Punjab. The tract is a vast desert of sand hills, covered with scrub jungle. Isolated wells, surrounded by small patches of cultivation, occur at rare intervals. Trees grow in a few parts of the desert only and the water from the wells is brackish.

The area of the Sutlej Valley Project lies between the old bed of the Beās river and the Sutlej river. Except for a strip along the latter, it consists of a flat plain covered with scrub jungle, many parts of which are without water. Such water as there is, is of a very inferior quality. Sand hills occur in parts of the area and the most noticeable feature is the "*Chit Dain*", a tract of very white sand on which a mirage of a broad sheet of clear water is continuously reflected. In both areas violent sand and dust storms occur in the beginning of April, and the work was often brought to a stand-still for two or three days owing to the density of the atmosphere that continued for a long time after the storms abated.

The head-quarters of the party opened in the field at Multān Cantonment on 25th October 1920 and closed on 5th May 1921. The office re-opened on 16th May 1921 at its recess head-quarters in Mussoorie.

The party was divided into 4 camps.

The health of the party was good, despite bad water and difficulty in obtaining supplies. One khalasi died.

Triangulation.—The nature of the country triangulated lay in the area of the Sutlej Valley Project and consisted of a highly cultivated area, thickly covered with trees, mostly date palm, bordering on the Sutlej river and a flat plain, covered with scrub jungle, to the north.

At first it was hoped to use the old secondary triangulation falling in the area, but none of the old stations were in existence. A new series of triangulation had, therefore, to be observed from the Sutlej Series of the G. T. Survey on the south bank of the river. This entailed heavy line clearing, as trees had grown up even between the several G. T. Stations and the banks of the river were thick with date palms.

Triangulation to fix corners of 2,400-acre rectangles was carried out by Mr. Amrit Ram and 3 surveyors under Mr. J. C. C. Lears, whilst Mr. J. C. C. Lears and Mr. D. N. Banerjee each ran a series of triangles, connecting the work with the Sutlej Series of the G. T. Survey on the south side of the river.

155 stations were observed at and 15 intersected points were fixed over an area of 647·35 square miles at a cost-rate of Rs. 38·4 per square mile.

Traversing.—No new traversing was undertaken this year as the Sind-Sāgar area had been completed in previous years and for the area demarcated in the Sutlej Valley area base lines laid down in 1906-07 and 1907-08 by old No. 18 Party were available.

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Rectangulation. Sind-Sāgar Doāb area.—The area laid down for rectangulation was completed this field season. The area in which the work was carried out is the "High" or "Grazing Thal". The tract is more bare and waterless than the rest of the area and consists of high sand hills and small depressions.

Rectangulation in this area consisted of (1) Location on the ground of corners of 4,000-acre rectangles from temporary marks near these corners, fixed previously by triangulation; this had already been completed for the area in previous seasons. (2) Location on the ground of 100-acre corners on the long sides of 4,000-acre rectangles with theodolite and short and long chains. (3) Sub-demarcation of the 4,000-acre rectangles into 100-acre rectangles by long chain measurement. In all cases the 100-acre corners were marked by embedding flat-topped monolith pillars, 6 inches square and 30 inches long. The work was carried out without much line clearing.

Almost 100 per cent of the work was tested by 2622·2 linear miles partalled by the Survey officers and superior revenue staff, an error of 1 in 1,000 only being allowed. 750·2 linear miles of partal of previous season's work was also carried out.

No. 1 Camp, under Mr. Nabidad Khan, consisting of 5 traversers, laid out 726 100-acre corners on the long sides of 4,000-acre rectangles.

No. 2 Camp, under Mr. Chuni Lal Kapur, consisting of 6 traversers, 1 naib tahsildar, 8 kanungos and 16 patwaris, laid out 3,399 interior 100-acre corners, in an area of 740 square miles.

No. 1 Camp completed work in this area on 20th January 1921 and No. 2 Camp on 31st January 1921.

The cost-rate worked out at Rs. 88·2 per square mile or Re. 0·14 per acre.

The total out-turn of rectangulation for the whole Sind-Sāgar area completed between 1917 and 1921 is as follows:—

1920 main corners of 2,000- and 4,000-acre rectangles located, 49,644 100-acre corners located, 50,774 100-acre rectangles laid out, comprising an area of 7,933·4 square miles.

Rectangulation. Sutlej Valley Project.—The area given for rectangulation is a tract between the old bed of the Beās and the Sutlej river, from the Multān-Lodhrān Railway on the west to the town of Pākpattan on the east. The north-west portion of this area was taken up this season. The area is a flat plain with occasional small hillocks, covered with scrub jungle, very thick along the north on the borders of the old bed of the Beās river. In the area are a few large villages, surrounded by a small area of poor cultivation, the remainder of the area is almost waterless and given over to the grazing of camels and goats.

The work consisted of:—(1) Location of main corners of 2,400-acre rectangles on the ground by means of traverse base lines previously laid down. (2) Location on the ground of 25-acre corners on long sides of 400-acre rectangles; both by means of theodolites and short and long chains. (3) Sub-demarcation of 4,000-acre rectangles into 25-acre rectangles by long chain measurement. All corners were marked by stone pillars similar to those used in the Sind-Sāgar area.

75 per cent of the work was tested by 2236·2 linear miles partalled by the Survey officers and superior revenue staff. An error of 1 in 500 was allowed, owing to this error being found in the laid out base lines, several of which were also found to be in error *in situ*, owing to mistakes in applying corrections when the pillars were embedded which caused extensive line clearing and the running of long test traverses for ascertaining the errors.

No. 4 Camp, consisting of 9 traversers, under Mr. D. N. Banerjee, commenced work on 21st November 1920 and laid out 3,397 25-acre corners on the long sides of 400-acre rectangles as well as 115 interior 25-acre corners in the process of correcting bases.

No. 1 Camp, consisting of 6 traversers, under Mr. Nabidad Khan, commenced work on 24th January 1921 and laid out 1,141 25-acre corners on the long sides and 99 interior 25-acre corners.

No. 2 Camp, under Mr. Chuni Lal Kapur, with 6 traversers, 1 naib tahsildar, 8 kanungos and 16 patwaris, commenced work on 6th February 1921 and laid out 3,876 interior 25-acre corners in an area of 270·4 square miles.

The cost-rate of rectangulation is Rs. 416 per square mile or Re. 0·65 per acre.

Recess Duties.—The strength of the party was reduced very considerably in recess. 9 traversers and the whole revenue staff were sent on departmental leave.

No. 1 Section, under Mr. J. C. C. Lears, assisted by Mr. Amrit Ram with 1 computer and 2 draftsmen completed the computations of the current season's triangulation and prepared supplementary triangulation charts for Degree sheets 33 O and 44 C.

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No. 2 Section, under Mr. Maya Das Puri, Rai Sahib, assisted by Mr. Nabidad Khan, until he proceeded on leave, and Mr. Chuni Lal Kapur with 5 traversers completed the records of the Sind-Sāgar and Sutlej Valley Rectangular Survey.

No. 3 Section, under Mr. D. N. Banerjee, with 6 traversers carried out miscellaneous drawing, such as preparation of index charts, and trained new traversers, in drawing, traversing, plotting etc.

Inspections.—The Superintendent, Northern Circle inspected the party in the field from 23rd to 27th January 1921 and in recess on 26th May 1921. The Surveyor General of India, accompanied by the Superintendent, Northern Circle inspected the party in recess on 7th September 1921.

No. 22 (RIVERAIN) PARTY (PUNJAB).

By Dhani Ram Verma.

The area dealt with by the party was of varied character. The riverain area under water action was usually broken and full of swamps and covered with shrubs, high grass and sand near the rivers but well cultivated away from them. Densely wooded patches of *Jand* and *Pilu* trees were occasionally met with along the Sutlej, and of *Babul* and *Jal* trees along the Chenāb. In the Khaur mining area, the ground was open and undulating with deep *nalas* and traversed by a chain of low bare rocky hills with a precipitous face on the north. The area covered by the Lahore Town Traverse was flat, congested and extensively cultivated, the Rāvi river passing through the western portion. The Lahore "Nazul" land was a plain waste land covered with low grass and road avenues.

The field operations in connection with riverain and other surveys for the Punjab Government were commenced in the middle of October 1920 and were finally brought to a close on 24th June 1921.

Personnel.

Class I Officer.

Mr. H. H. B. Hanby, in charge from 10th February to 20th May 1921.

Class II Officers.

Mr. Dhani Ram Verma, in charge from 8th November 1920 to 9th February 1921 and again from 21st May 1921 and attached from 10th February to 20th May 1921.
„ Maya Das Puri, Rai Sahib, in charge till 7th November 1920.
„ Abdul Karim, B.A., from 5th December 1920.

Upper Subordinate Service.

Mr. Jamna Prasad, R.S., from 29th March 1921.
„ Ram Narayan Hastir.
„ Vidya Dhar Chopra, till 30th April 1921.
„ Gulab Singh, from 11th May 1921.

Lower Subordinate Service.

48 Surveyors, etc.

One traverser was however employed in August and September 1921 on the Lahore "Nazul" land survey.

The head-quarters of the party remained at Lahore throughout the year.

The health of the party was good throughout the season; one traverser (re-employed) suffered from pneumonia. In recess one computer died of pneumonia and one tindal died of heart failure due to abnormal heat.

2. The detail traversing on the Chenāb in the Muzaffargarh *tahsīl* was carried out under Mr. Ram Narayan Hastir and on the Sutlej in the Pākpattan and Dīpālpur *tahsīls* under Mr. Vidya Dhar Chopra and surveyor Ishwar Singh and subsequently under Mr. Ram Narayan Hastir. The base lines on the Sutlej were laid out under Mr. Ram Narayan Hastir. The main circuits on the Panjnad were run by traversers Roda Ram and Dial Singh working independently. The traversing of Lahore and its environs was carried out under Messrs. Dhani Ram Verma and Abdul Karim. The traversing and levelling and the topography of the Khaur Special Survey were supervised by surveyor Ishwar Singh. The Lahore "Nazul" land survey was done directly under the officer in charge of the party.

During the field season the computing and *masāvi* sections at the head-quarters were supervised by computer Badlu Ram and draftsman Makbul Husain respectively.

3. The party continued the work of traversing and laying out base lines. 189 linear and 225 square miles of main circuits with 3,373 linear and 526 square miles of minor traverse were executed. 323 theodolite stations of the former and 14,272 of the latter were fixed in 258 villages. 363 corners of 121 squares were demarcated in 375 square miles with permanent mark-stones on both banks of the Sutlej river in district Montgomery and Bahāwalpur State to serve as bases for future survey and demarcation of boundaries and fields in the bed of the river, 2,156 plotted and 649 boundary *masāvis* (settlement mapping

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sheets) on the scale of 1/2,640 and 37 four-inch sheets were traced and supplied in time to the Settlement Officers Muzaffargarh and Montgomery. In addition 533 boundary *masāvis* were partly compiled on the scale 1/2,640 in advance for the next field season's work, and all the traverse stations marked during the year were plotted on 38 four-inch sheets. 4,227 pages of field books and 894 of set-up, forming 19 volumes of field books and 11 volumes of set-up of the riverain work of the year, were completed.

The minor traverse was based on the main circuits run in the previous seasons. The average daily out-turn per man was 7·3 stations and 1·71 linear miles.

The main circuits on the Panjnad were connected with Thal Megrāj T.S. LXXXVII of the Great Indus Series and Paphra T.S. IV and Khānbela T.S. II of the Sutlej Series, and 9 azimuths were taken. The average daily out-turn per man was 3·7 theodolite stations and 2·14 linear miles.

The average daily out-turn of laying out base lines per man was 3 corners.

There was general scarcity of labour and transport, especially towards the Bahāwalpur side and much jungle clearing had to be done along the Chenāb and Sutlej rivers. Much time was wasted on account of stones for base lines not having been supplied in time by the Settlement Officer Montgomery, the survey staff helped in the transportation *of* the stones to the depôts.

4. The following tables give full details of the riverain work completed during the year :—

FIELD WORK.

Names of Rivers and Districts and Scales.	Main-circuit.				Minor Traverse for Detail Survey.					Base-lines.			Remarks.
	Straight length in miles.	Number of square miles.	Number of linear miles.	Number of theodolite stations.	Straight length in miles.	Number of square miles.	Number of linear miles.	Number of theodolite stations.	Number of villages.	Number of corners.	Number of squares.	Area in square miles.	
Sutlej River. District Montgomery and Bahāwalpur State, Scale 1/2,640.	...	...	...	...	68	220	1,306 107*	5,738 490*	101	363	121	375	*Of base lines.
District Montgomery and Ferozepur, Scale 1/2,640	...	...	...	...	25	96	906	3,553	75	...	...	...	
Chenāb River. District Multān and Muzaffargarh, Scale 1/2,640.	...	...	...	...	80	210	1,054	4,491	82	...	...	...	
Panjnad River. District Muzaffargarh and Bahāwalpur State.	36	225	189	323	...	...	...	...	...	...	...	...	
Total	36	225	189	323	173	526	3,373	14,272	258	363	121	375	

OFFICE WORK DONE FOR THE CADASTRAL SURVEYS OF RIVERAIN ESTATES.

Name of river.	Name of district.	Scale of *masāvis*.	Number of plotted *masāvis* showing traversed points.	Number of compiled *masāvis* showing riverain boundaries.	Number of sheets traced for the use of settlement officers on scale 4 inches = 1 mile.	Number of 4-inch sheets on which new work was plotted.
Sutlej ...	Montgomery ...	1/2,640	1,385	416	23	23
Chenāb ...	Muzaffargarh ...	1/2,640	771	233	14	15
	Total ...	...	2,156	649	37	38

Besides these 270 miscellaneous traces were prepared and 533 boundary *masāvis* were partly compiled in advance for the next season's work.

5. *Lahore Town Traverse.*—This was undertaken at the request of the Sanitary Commissioner, Punjab for the large scale survey of Lahore and its environs for the purpose of sanitary improvement.

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Three different scales, *i. e.*,

(i) 1 inch=100 feet for Lahore Town proper and the congested areas outside the old city walls,

(ii) 16 inches=1 mile for the rest of the municipal area,

(iii) 6 inches=1 mile for an area one and a half miles in breadth all round the municipal limit,

were proposed by the Sanitary Commissioner. Traverse lines had to be run with due regard to the scales. Arrangements with local authorities for police protection etc., took much time. It was commenced in February and finished in June 1921. It was very carefully done but for want of G. T. stations could only be connected with Lahore Anārkali's Tomb, Ichra Temple, Miān Mīr Church, Lahore Sonahri Masjid, Shāhdara Minaret, the points of the Gurhāgarh Meridional Series, and *pucka* trijunction pillar (Jia Mūsa, Kot Begam and Kot Mahibbo villages) fixed in season 1912-13 and the pillars of base line No. 33 of *mauza* Baddo and those of base line No. 38 of *mauza* Sherkot on the left bank of the Rāvi river laid down in season 1913-14. In all 6,485 theodolite stations were laid down and 644 linear miles traversed, covering an area of approximately 63 square miles. 8 azimuths were taken. 234 intersected points such as chimneys, spires of churches, temples, mosques and conspicuous trees were fixed, the last ones particularly in the 6-inch area. The traverse stations in the town were marked with 9-inch iron nails with round flat tops of 2-inch diameter and in the outer area with stones 6 inches × 6 inches × 10 inches with ⊙ cut into the top and embedded flush with the ground. The unceasing traffic in the *bāzārs*, excessive heat and frequent violent dust storms impeded the work and lessened the out-turn. The daily averages of out-turn per man were as given below:—

Survey on scale.	Theodolite stations.	Linear miles.
1 inch=100 feet ...	6·6	0·18
16 inches=1 mile ...	6·6	0·65
6 inches=1 mile ...	6·1	1·29

1,983 pages of field books forming 9 volumes and 455 pages of set-up forming 4 volumes were completed. All the traverse stations and points were plotted on 8 eight-inch sheets and 8 traces of the same were prepared for binding in the computation volumes.

6. *Khaur Special Survey.*—This was undertaken for the Attock Oil Company at their request through the Deputy Commissioner, Attock district. The work consisted in contouring at 10-feet intervals the area surveyed for them on the eight-inch scale without contouring in season 1915-16 and surveying on the same scale with contours at 10-feet intervals the adjacent area in the neighbourhood of Khaur village (*tahsīl* Pindi Gheb, district Attock) and demarcation of the boundary of the new area for lease.

The topography was based on traverse and levelling emanating from Khaur h. s., the only trigonometrical station with a known height in the area. The traverse stations of season 1915-16 were almost all lost. Some of them were identified by old angles and measurements. Owing to the hilly nature of the ground subtense bar had to be frequently used in traversing. In all, 330 theodolite stations were laid down and 109·46 linear miles were traversed and 91 intersected points with heights were fixed to assist in plane-tabling. Computation was done *pari passu* in the field. 43·05 linear miles were levelled and 1,235 stations were laid down and 80 bench-marks were fixed. The total area plane-tabled was 8 square miles. The survey was carried out by interpolation. The daily averages per man of traversing, levelling and plane-tabling were as given below:—

Description of work.	Stations.	Linear miles.	Square miles.
Traversing	5	1·63	...
Levelling	43	1·48	...
Survey (revision and original)	...	...	0·15

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The field work was commenced in January and finished in March 1921.

The average cost-rates of traversing and levelling per linear mile and surveying per square mile were Rs. 32·3 and Rs. 121·5 respectively.

139 pages of field book forming 1 volume and 77 pages of set-up forming 1 volume were completed, 4 miscellaneous traces were prepared and all the traverse stations marked and intersected points were plotted on three 8-inch sheets and three traces of the same were made for binding with the computations.

7. *Lahore "Nazul" Land Survey,* on the scale of 1 inch = 40 feet, was undertaken in August 1921 at the request of the Deputy Commissioner, Lahore in connection with Lahore City extension scheme. The survey was based on the traverse already done in connection with the Lahore town survey. It was commenced towards the end of August 1921. The municipal engineer in charge of the scheme asked for the survey of the adjacent congested portion of the city in addition to that originally asked for. It will probably be completed in October 1921. The area surveyed up to the end of September 1921 was 33·5 acres and its cost-rate was Rs. 6·4 per acre.

8. The average errors were as follows :—

(*a*) Base-lines :—

0·94 foot per corner of riverain base-line as compared with its theoretical value.

	Angular error per station in seconds.	Linear error in links per 10 chains.
(*b*) Main Circuits		
Panjnad River	3·82	0·34
Lahore Town	2·08	0·27
(*c*) Minor Traverses		
Sutlej River	8·25	0·78
Chenāb River	8·50	0·92
Lahore town, average of 3 scales	2·24	0·48
Khaur oil mining area	5·24	0·92

9. *Recess Duties.*—(*a*). Mr. Gulab Singh was in charge of the computing section consisting on the average of 16 computers etc. The section completed all traverse computations appertaining to the work of the year and its records detailed in the previous paragraphs. Besides this 1,500 pages of field books forming 4 volumes and 423 of set-up forming 2 volumes of the riverain traverse of the Rājanpur *Tahsīl* (Dera Ghāzi Khān) executed in seasons 1915-19 were completed.

(*b*). Mr. Jamna Prasad, R. S., was in charge of the compiling and plotting section consisting on the average of 17 draftsmen etc. The section partly compiled 533 boundary *masāvis* for the next season's work and prepared 8 eight-inch plot sheets of Lahore town traverse. Besides this it made miscellaneous traces and prepared field traverse charts for the use of the traversers in the next field season.

(*c*). Mr. Ram Narayan Hastir was in charge of the triangulation and traverse chart section consisting on the average of 4 computers and draftsmen. The section prepared manuscript charts for the degree sheets 43/L and 44/B.C.E.F.G but could not finish them for want of old Lower Bāri Doāb data not returned by the Sind-Sāgar Party. In addition the section compiled data for 6 more charts, Nos. 44/J.M.N and 53/A.B.F to be taken up in next recess.

10. The total expenditure of the party from the 1st October 1920 to the 30th September 1921 was Rs. 145,179 as detailed below :—

Riverain survey	...	...	...	Rs. 112,268
Lahore town traverse	...	...	...	Rs. 28,203
Khaur special survey	...	...	...	Rs. 4,492
Lahore "Nazul" Land survey	...	...	...	Rs. 216

11. *Inspections.*—The party was inspected by the Superintendent, Northern Circle in November 1920 and again in January 1921.

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SOUTHERN CIRCLE.

(*Vide* INDEX MAP No. 1)

Summary.—This circle was under the superintendence of Lieut.-Colonel C. P. Gunter, O. B. E., R. E., up to the 19th October 1920 and again from 1st February 1921 to the 15th March 1921, under Brevet-Colonel F. W. Pirrie, C. M. G., C. I. E., I. A., from the 20th October 1920 to the 31st January 1921 and under Lieut.-Colonel H. H. Turner, R. E., from the 16th March 1921. It comprised Nos. 5, 6, 7, 8 and 20 Parties, No. 4 Drawing Office, Record Section and the Training Section.

During the field season Nos. 5, 7 and 8 Parties completed 14,275 square miles of detail survey on the two-inch and one-inch scales and Nos. 5 and 6 Parties completed 2,869 square miles of triangulation. During recess the fair-mapping of the area surveyed was taken up and will be completed before the parties again proceed to the field.

The detail survey consisted of:—

6,454 square miles of one-inch original survey.
727 „ „ „ one-inch revision survey.
6,353 „ „ „ one-inch supplementary survey.
671 „ „ „ two-inch original survey.
70 „ „ „ two-inch supplementary survey.

In order to effect a saving on the budget the head-quarters of No. 6 Party remained at Bangalore, a small triangulation detachment only being sent into the field. The party was employed on half-inch and other mapping.

No. 20 Party surveyed an area of 15,467 acres = 24·2 square miles in cantonments and military stations.

The detail survey consisted of:—

9,111 acres of sixteen-inch original survey.
5,583 „ „ sixteen-inch revision survey.
283·5 „ „ sixty-four-inch original survey.
489·4 „ „ fifty-foot original survey.

14 Upper Subordinate probationers joined the department during the year and were allocated to this circle for a course of training under the Officer in charge No. 6 Party. One probationer resigned during the year.

Of the 20 pupil surveyors originally recruited during the year, two were discharged and their places were filled by new recruits.

No. 5 PARTY (BERĀR, BOMBAY, CENTRAL INDIA AND CENTRAL PROVINCES).

BY CAPTAIN G. LENNOX, I. A.

This party took the field in full strength and completed the detail survey on the 1-inch scale of sheets 46 N/16, 55 B/4 and 55 C/1.2.3.4.5.6.7.8.9.10.13.14.

PERSONNEL.

Class I Officers.

Major L. C. Thuillier, I. A., in charge to 24th February 1921.
Captain G. Lennox, I. A., (on probation) in charge from 25th February 1921.

Class II Officers.

Mr. F. C. Pilcher.
„ F. W. Smith.
„ Muhammad Najamuddin, B. A. (on probation) from 21st October 1920.

Upper Subordinate Service.

Mr. P. S. Vengusvami.
„ J. A. Cabral, (on probation) from 1st November 1920.

Lower Subordinate Service.

32 Surveyors, etc.

The party also completed the triangulation of sheets 46 N/9.10.11.12.13.14.15.16.

The general nature of the country is intricate, jungle clad hills and highly cultivated well wooded plains.

The field season opened at Itārsi on the 1st November 1920 and closed on the 9th April 1921. The field head-quarters of the party was transferred from Itārsi to Khandwā on the 8th November 1920 and remained there throughout the field season.

The health of the party in the field was on the whole very good.

Plane-tabling.—The nature of the country surveyed varies. On the north are rolling wooded hills along the course of the Narbadā river. South of this is a well wooded plain containing the civil station of Khandwā and bounded on the west, south and east by the intricate, jungle clad hills of the Sātpurā Range. In the south

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the river Tāpti and its tributary the Pūrna flow through cultivated plains interspersed with jungle covered hills.

The survey was carried out by three camps as under :—

No. 1 Camp.—Under Mr. F. C. Pilcher, sheets 46 N/16, 55 B/4, and 55 C/1. 2. 5.

No. 2 Camp.—Under Mr. F. W. Smith, sheets 55 C/6. 9. 10. 13. 14.

No. 3 Camp.—Under Mr. P. S. Vengusvami, sheets 55 C/3. 4. 7. 8.

The 1-inch survey called for no special note. The one-inch supplementary survey was carried out by transferring the photographic reductions of previous four-inch forest surveys to the plane-table sections after having re-surveyed the boundary and checked the detail.

Triangulation.—Triangulation was carried out by surveyor Nur Muhammad in sheets 46 N/9. 10. 11. 12. 13. 14. 15. 16. The nature of the country triangulated is, in the north, the cultivated plateau around the city of Indore and in the centre and south, jungle clad hills of the Vindhya and Sātpurā Ranges divided by the broad alluvial valley of the Narbadā.

Recess Duties.—(*a*) The fair-mapping of the party was divided into three sections as under :—

No. 1 Section.—Under Mr. F. C. Pilcher, sheets 46 N/16, 55 B/4 and 55 C/1.2.5.

No. 2 Section.—Under Mr. F. W. Smith, sheets 55 C/6. 9. 10. 13. 14.

No. 3 Section.—Under Mr. P. S. Vengusvami, sheets 55 C/3.4.7.8.

There are no arrears of fair-mapping, all sheets having been submitted for publication.

(*b*). All computations have been completed.

All triangulation charts and pamphlets have been handed over for completion to the officer in charge of the Record Section, Southern Circle.

Inspections.—The party was inspected during recess by the Surveyor General and by the Superintendent, Southern Circle.

No. 6 PARTY (BOMBAY, MADRAS AND HYDERĀBĀD).

By H. B. Simons.

The head-quarters of the party remained at Bangalore throughout the year and completed the fair-mapping of four-inch, three-inch, two-inch, one and a half-inch, one-inch, and three quarter-inch sheets.

PERSONNEL.

Class I Officers.

Lieut.-Colonel C. P. Gunter, O. B. E., R. E., in charge from 20th October 1920 to 31st January 1921, and from 16th March to 15th August 1921.

Mr. J. O' B. Donaghey, in charge to 19th October 1920.

Class II Officers.

Mr. H. B. Simons, in charge from 16th August 1921.
„ E. A. Meyer, in charge from 1st February to 15th March 1921.
„ Munshi Lal, B. A.
„ N. S. Harihara Iyer.
„ E. N. Natesan, B. A., to 28th February and from 1st May 1921.

Upper Subordinate Service.

Mr. K. G. Mandanna.

Lower Subordinate Service.

25 Surveyors, etc.

Two triangulators were sent to supplement the triangulation for two-inch surveys of Amrābād Reserve Forest in Mahbūbnagar district of His Exalted Highness the Nizām's Dominions (Hyderābād, Deccan) falling in sheets 56 L/11. 12. 15. 16.

Plane-tabling.—No plane-tabling was executed.

Triangulation.—The nature of the country comprised high lying plateaus covered with impenetrable forest and intersected by narrow precipitous valleys. The absence of communication, scarcity of water and inadequate labour added to the difficulties of the triangulators. Triangulation was carried out in sheets 56 L/11. 12. 15. 16 by Messrs. E. N. Natesan, B. A., and K. G. Mandanna. The former was transferred to No. 7 Party from 1st March 1921, leaving the work to be completed by the latter.

Recess Duties.—(*a*) A fair-mapping section under Mr. E. A. Meyer till 28th March 1921 and under Mr. H. B. Simons from 5th April 1921, dealt with 36 two-inch special forest maps of last season's fair-mapping and submitted them for publication. The three-inch Secunderābād military map was also completed and sent for publication. In addition two sheets of the South-West Persia Survey Detachment, (four-inch Būshire and one-inch Shīrāz), also one and a half-inch sheets of the Training Section (57 G/10. 14) were taken in hand. With the exception of the four-inch Būshire map which is under reference to the Resident, Būshire, all others will be submitted for publication before the party leaves for the field.

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A section under Mr. Damodar Khadilkar was temporarily attached to this party till 1st August 1921 and was employed on fair-mapping half-inch sheets made over by No. 7 party on their taking the field in November 1920. Of these sheets 57 N/NE. was completed and despatched for publication, the remainder being sent back with the section, to be completed under the Officer in charge No. 4 Drawing Office.

(*b*) The computations of the season's triangulation have been completed by Mr. E. N. Natesan, B. A., assisted by Mr. K. G. Mandanna.

No. 7 PARTY (MADRAS).

By Major J. D. Campbell, D. S. O., R. E.

This party completed the detail survey of sheets 56 P/7.11.12.15.16, 57 M/1.2.3.4.5.6.7.8.11 and 57 G/10.14 and of the area falling in the Madras Presidency of sheets 56 P/2.3.6.10 on the one-inch and two-inch scales, part of 57 G/6 on the one-inch scale and reserved forests in 56/P4.8.14 on the two-inch scale.

Personnel.

Class I Officer.

Major J. D. Campbell, D. S. O., R. E., in charge.

Class II Officers.

Mr. F. H. Grant.
" A. F. Murphy.
" N. S. Harihara Iyer, from 1st March 1921.
" E. N. Natesan, B. A., from 1st March to 30th April 1921.

Upper Subordinate Service.

Mr. K. Narayanasvami Chetti.
" Damodar Khadilkar up to 31st July 1921.
" Shib Lal.
" Shadi Lal Dube.

Lower Subordinate Service.

34 Surveyors, etc.

The nature of the country generally comprised cultivated open expanses of level or undulating land and isolated rocky scrub-covered hills. On the west, it included the eastern slopes and foothills of the Nallamalais and part of the Donakonda range, covered with jungle of varying density.

The office of the party closed at Bangalore on 21st October 1920, and opened at Mārkāpur, the field head-quarters, on 1st November 1920. The office was closed at Mārkāpur on 26th April 1921 and opened at Bangalore on 3rd May 1921. There was practically no rain during the field season.

The health of the party was very good.

Plane-tabling.—The country surveyed is mostly flat or slightly undulating, open and cultivated, the cultivation being nearly all dry except for small areas near tanks.

The hill ranges are mostly boulder strewn and covered with thorny scrub. The survey presented no difficulties. Chaining had only to be resorted to in the case of a few dense and flat jungle areas near the Kistna river.

Work was done on blue prints on mounted strawboards of both Madras Revenue Survey work and four-inch forest surveys. In the case of the latter, one-inch reductions were printed in blue and detail required on that scale inked up. Tops of hills, spurs, saddles etc., were indicated and the contouring done in the field with the aid of the original four-inch maps.

Difficulties were experienced with regard to water and transport. The monsoon had been deficient and added to the scarcity of water in a tract always scarcely supplied. Some surveyors in forest areas had to send a long way for water. Carts were difficult to obtain at legal rates.

The work was divided into four camps, and one surveyor and one Class II officer worked independently, as follows:—

No. 1 Camp.—Under Mr. F. H. Grant, with 8 surveyors completed the two-inch survey in sheets 56 P/12.14.15.16 and parts of 56 P/10.11. This camp was taken over by Mr. A. F. Murphy on the 6th March. The strength of the camp was ultimately increased to 11 surveyors and the one-inch work in sheets 56 P/12.15.16 not included in the original programme, was taken up and completed.

No. 2 Camp.—Under Mr. A. F. Murphy, with 5 surveyors and 3 pupils, surveyed sheets 57 M/6.7.8.11 and part of 57 M/4 including small reserved forest areas on the two-inch scale. Mr. Murphy handed over his remaining surveyors to Mr. K. Narayanasvami Chetti and took over charge of No. 1 Camp on 6th March.

No. 3 Camp.—Under Mr. K. Narayanasvami Chetti with 5 surveyors and 3 pupils, surveyed sheets 57 M/1.2.3.5 and part of 57 M/4 including small reserved forest areas on the two-inch scale.

No. 4 Camp.—Under Mr. Shib Lal with 8 surveyors completed the two-inch survey in sheets 56 P/2.3.4.6.7.8 and parts of 56 P/10.11. The strength of the camp was ultimately increased to 10 surveyors and the one-inch work in sheets 56 P/2.3.6.7.10.11 not included in the original programme, was taken up and completed. The survey in sheets 56 P/2.3.6.10 was

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completed to the Madras-Hyderābād boundary only, as the remainder of these sheets will be surveyed on the half-inch scale.

Independent Surveyors.—1st class surveyor B. Jagan Nathan carried out revision of the training school work in 57 G/6.10.14 and completed the unsurveyed portion of 57 G/14. Mr. N. S. Harihara Iyer started the survey of the unsurveyed portion of 57 G/6 on 6th March but did not complete the area.

Triangulation.—No triangulation was carried out.

Recess Duties.—(*a*) The fair-mapping was divided into four sections as follows:—

No. 1 Section.—Under Mr. Murphy, sheets 57 M/6.7.8.11.

No. 2 Section.—Under Mr. Narayanasvami Chetti, sheets 57 M/1.2.3.4.

No. 3 Section.—Under Mr. Shib Lal, sheets 56 P/6.7.10.11 including 56 P/2.3 as outriggers to 56 P/6.7.

No. 4 Section.—Under M. Shadi Lal Dube, sheets 57 M/5 and 56 P/12.14.15. All sheets will be sent for publication before the end of recess.

(*b*). No computations or triangulation charts are in hand, there being no arrears.

The preparation of reductions of the 4-inch maps for the next field season formed a large part of the work during recess. It was decided to accept the contouring on the four-inch maps to a greater extent than hitherto and contours were inked up on the blue print reductions instead of form lines showing tops, saddles etc. This has proved very laborious, but it is hoped that it will result in a greatly increased out-turn in the field.

No. 8 PARTY (MADRAS).

By Lieut.-Colonel M. O'C. Tandy, D. S. O., O. B. E., R. E.

This party completed the detail survey on the one-inch scale of sheets 58 F/3.4.7.8. 58 G/5.6.9.10.13.14, 58 K/1.2.5.6.9.10.13.14 and about 50 square miles of reserved forest in sheets 58 F/7.8 on the two-inch scale.

The field season opened with head-quarters at Kodaikānal on 19th November 1920 and closed there on 15th May 1921.

The health of the party was good with the exception of the surveyors working in the hills bordering the Kambam valley and in parts of Travancore State and the Palni hills. In these areas fever and malaria were very prevalent.

The country surveyed presented no unusual features; near the sea the country is flat and almost entirely under wet cultivation, the water being supplied from numerous tanks, the flatness of the country and the great number of palmyra and palm trees make it often impossible to survey by resection and plane-table traverses have to be resorted to; further inland and near the hills the black soil of the plains gives place to red soil under dry cultivation and the presence of small isolated hills and rocky outcrops provides good points on which to base triangulation and traverse; the hill portions of the area surveyed included the highest hill in Southern India, Anaimudi, height 8,841 feet; throughout this hilly area survey was much interfered with by mist clouds. Sometimes for days together the surveyors were unable to get fixings from the triangulated hill tops, this was particularly the case at the beginning and end of the field season; from the middle of January to the end of March may be taken as the best time of year for surveying in the hills of Southern India. The hills bordering the Kambam valley were densely wooded and sparsely inhabited, the surveyors often had great difficulty in obtaining water and herds of wild elephants at times delayed the survey; portions of the Travancore State hills and the Palni hills were also heavily wooded.

Supplementary survey based on blue prints of the Madras Revenue Survey was carried out in the cultivated area of the plains; in the Palni hills and the hills bordering the Kambam valley, supplementary surveys were based either on departmental forest surveys on the four-inch scale or on the one-inch departmental surveys of 1886-88. Original survey was only necessary in about 345 square miles, chiefly in Travancore State.

Personnel.

Class I Officer.

Lieut.-Colonel M. O'C. Tandy, D. S. O., O. B. E., R. E., in charge from 26th October 1920.

Class II Officers.

Mr. C. E. C. French, in charge till 25th October 1920.
„ M. Mahadeva Mudaliar, M. A.
„ B. T. Wyatt.
„ M. S. Ganesa Aiyar.
„ J. C. St. C. Pollett.
„ J. A. Calvert, from 16th October 1920.

Upper Subordinate Service.

Mr. H. Narasimhamurti Rao.
„ Shaikh Muhammad Salik.
„ Abdul Ghafur, from 1st April 1921.

Lower Subordinate Service.

49 Surveyors, etc.

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The *field work* was divided into 5 camps.

No. 1 Camp.—Under Mr. M. Mahadeva Mudaliar, assisted by Mr. Shaik Muhammad Salik with 14 surveyors completed 43 square miles of original two-inch survey and 5 square miles of supplementary survey on the two-inch scale and 303 square miles of original and 818·03 square miles of supplementary survey in sheets 58 F/3.4.7.8, on the one-inch scale.

No. 2 Camp.—Under Mr. M. S. Ganesa Aiyar took the field with 6 surveyors, but towards the end of the season owing to delay due to the difficulty of surveying in the Kambam valley hills this number had to be increased to 9, this camp completed 824·08 square miles of one-inch supplementary survey in sheets 58 G/5.6.9.

No. 3 Camp.—Under Mr. B. T. Wyatt with Mr. H. Narasimhamurti Rao and 6 surveyors completed 1,171·40 square miles of one-inch supplementary survey in sheets 58 G/10.13.14 and 58 K/2.

No. 4 Camp.—Under Mr. J. A. Calvert with 8 surveyors completed 878·27 square miles of one-inch supplementary survey in sheets 58 K/1.5.6.

No. 5 Camp.—Under Mr. J. C. St. C. Pollett with 8 surveyors completed 1,118·10 square miles of one-inch supplementary survey in sheets 58 K/9.10.13.14.

No *triangulation or traverse* was done during this season.

Recess Duties.—The fair-mapping was divided into 4 sections as follows:—

No. 1 Section.—Under Mr M. Mahadeva Mudaliar assisted by Mr. Abdul Ghafur, sheets 58 F/3.4.7.8.

No. 2 Section.—Under Mr. B. T. Wyatt, sheets 58 G/10.13.14 and 58 K/1.2.

No. 3 Section.—Under Mr. M. S. Ganesa Aiyar, sheets 58 G/5.6.9.

No. 4 Section.—Under Mr. J. C. St. C. Pollett, sheets 58 K/5 6.9.10.13.14.

Mr. J. A. Calvert was on leave during the greater part of recess.

Messrs. Shaik Muhammad Salik and H. Narasimhamurti Rao were employed preparing computations and plane-tables for the supplementary surveys of next field season.

All fair-drawing will probably be completed before the party takes the field but the final examination of some of the hill sheets may have to be completed at camp head-quarters.

No. 20 PARTY (CANTONMENT).

By Captain J. K. Douglas, R. E.

During the year under report the party continued survey operations in the Southern Circle.

The head-quarters of the party was at Bangalore.

The health of the party on the whole has been good.

The triangulation and traversing of Deolāli cantonment have been completed during the year.

The survey and contouring on the 16-inch scale of the following cantonments and military lands have been completed:—Wellington, Wellington Sanitary area, Wellington Catchment area, Aravanghāt (Aruvankādu) Cordite Factory grounds, Kārteri Cordite Factory grounds, water supply channel from Bairani stream to the Cordite Factory boundary, drinking water supply channel from Dodabetta to Cordite Factory boundary, High Tension line from Kārteri to Aravanghāt (Aruvankādu), Kaity rest camp, Lovedale Estate and extension for Lawrence Memorial School and ground on which military buildings at Ootacamund are erected, Cannanore, West Hill (Calicut) and Velichi military lands.

The surveys of the following bāzārs on the 64-inch scale were also completed:—St. Thomas's Mount, Poonamallee, Pallāvaram and Cannanore.

The surveys of the Bangalore Civil and Military Station on the sixteen-inch scale and of the General, Shūle, Halsūr Bāzārs and Arab lines, Bangalore on a 50 feet to an inch scale are in progress and almost completed.

Plane-tabling.—The accuracy of the detail survey (vide Table I) was tested by 75·5 linear miles and 188 *in situ* fixings.

Triangulation.—Mr. Wilson was employed on the triangulation of Deolāli, 14 stations and 18 intersected points were fixed on an area of 56 square miles.

Personnel.

Class I Officers.

Mr. B. R. Hughes in charge till May 1st 1921.
Captain J. K. Douglas, R. E. (on probation), in charge from 2nd May 1921.

Class II Officer.

Mr. J. H. S. Wilson.

Upper Subordinate Service.

Mr. Dharmu.
„ J. M. Mukerji.

Lower Subordinate Service.

31 Surveyors, etc.

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Traversing.—During the year Messrs. Wilson, Dharmu and 3 surveyors have been employed on traversing in Deolāli and Bangalore.

Levelling.—50·9 linear miles of levelling have been run in cantonments at a cost of Rs. 83·9 per linear mile.

Recess Duties.—The fair-mapping for the season includes the following cantonments:—Secunderābād, Cannanore, Pallāvaram, St. Thomas's Mount, Poonamallee and Bangalore Cantonment and Bāzārs, Madras district military lands, Velichi military lands, Wellington and West Hill cantonments and comprised 231 sheets on the sixteen-inch, sixty-four-inch and fifty-foot scales.

87 fair sheets have been submitted for publication, 61 more sheets have been completed, and 83 remain to be completed.

TRAINING SECTION.

By S. S. McA'F. Fielding.

Upper Subordinates.—14 probationers were appointed to the Upper Subordinate Service on 3rd January 1921. They received preliminary training in Bangalore in the rudiments of surveying with plane-table and chain, in theodolite work and drawing for the first two months and took the field on 3rd March with Mr. F. H. Grant, Extra Assistant Superintendent as instructor for regular training in plane-tabling.

PERSONNEL.

Class I Officer.

Lieut.-Colonel C. P. Gunter, O. B. E., R. E., from 3rd January to 15th August 1921.

Class II Officer.

Mr. S. S. McA'F. Fielding from 16th August 1921.

Instructors.

Mr. F. H. Grant from 1st March to 31st May 1921.
„ V. W. Morton from 1st June 1921.

Upper Subordinate Probationers.

Mr. Mauji Ram Sharma.
„ Janam Raj Chibbar.
„ T. S. Narayanan, B. A.
„ Mohabat Lal Kohli.
„ Dalip Singh.
„ Narayana Chandra Roy.
„ Rohini Kumar Talapatra, B. A.
„ Atul Chandra Maulick.
„ Abani Kumar Sen Gupta.
„ Mohammad Jamsed.
„ Suresh Chandra Chatterjee, B. Sc.
„ Mohammad Abdus Sattar.
„ K. B. Muthanna.
„ *Subodh Chandra Burdhan, B. A.

* Resigned on 3rd June 1921.

The ground selected for instructional survey was in sheet 57 G/12 in the neighbourhood of Dod-Ballāpur and Mākalidurga, about 40 miles north of Bangalore.

The class was inspected in the field on 4th, 5th and 6th May by Lieut.-Colonel C. P. Gunter, O.B.E., R. E., in charge No. 6 Party and then returned to recess quarters in Bangalore. The time spent on plane-tabling in the field was inadequate for training.

During recess the members were trained under Mr. V. W. Morton, Extra Assistant Superintendent in triangulation round about Bangalore, in theodolite traversing, levelling and field astronomy whenever the weather permitted.

Much time was spent on triangulation owing to wet weather. Computations of all topographical work were carried out, the majority doing well.

The Superintendent, Southern Circle inspected the class early in October 1921, after which 8 officers were drafted to parties and 5 remained for further training in plane-tabling and will take the field with the Training Section early in November.

Lower Subordinates.—The section took the field on completion of preliminary training in Bangalore, on 2nd November.

PERSONNEL.

Class II Officer.

Mr. S. S. McA'F. Fielding.

Lower Subordinates.

23 Surveyors and pupils.

The head-quarters of the section was situated at Kolār Town, the head-quarters of the district of that name, throughout the field season.

At the beginning of the year the section comprised 21 pupils, of these 1 pupil was transferred to No. 8 Party during the field season, 6 others to various parties during recess and 4 others were discharged. The remaining 10 continued their training till the end of the year.

In May 1921 a new class of 22 pupils joined the section and underwent preliminary training in drawing and plane-tabling, 2 of these pupils were discharged in June and August 1921.

The area which had been specially selected for instructional work, lay in sheet 57 K/4 and as had been anticipated, proved suitable in every way. The hills in the centre of the sheet enabled the majority of the pupils to get instruction in sketching and contouring. The low ground was sufficiently undulating to admit of accurate contouring at 25 feet vertical interval, and possessed a fair amount of varied detail.

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Communications throughout the sheet were excellent—metalled roads traversing the country in all directions, and a light railway running north and south through the area under survey.

The health of the section was on the whole very good. There was an outbreak of a type of influenza towards the close of the season which incapacitated a large number of the menials but all cases were successfully treated at the local hospital.

The field season closed about 18th April when the section returned to recess quarters in Bangalore.

The area surveyed in the field approximated 338 square miles, or an average of 16 square miles per man. The whole of sheet 57 K/4 was not completed, an area of about 40 square miles remaining unsurveyed. In several cases where the ground was suitable, surveys of 2 adjoining plane-tablers overlapped, and in the hills, the majority went over the same portion of ground on their margins.

On return to recess quarters, the pupils were started on a course of instruction in fair-mapping and the use of the line and swivel pens.

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EASTERN CIRCLE.

(*Vide* Index Map No. 1).

Summary.—This circle was under the superintendence of Lieut.-Colonel E. T. Rich, C. I. E., R. E., up to 22nd November 1920 and thereafter under that of Colonel W. M. Coldstream, R. E. to the close of the survey year. It comprised Nos. 9, 10, 11, 12 and 21 Parties and No. 5 Drawing Office, exclusive of survey units of Local Governments under the administrative charge of the Superintendent.

The detail survey consisted of :—

6,476	square miles	of	half-inch original survey.
3,609	„	„	„ one-inch original survey.
703	„	„	„ one-inch supplementary survey.
182	„	„	„ one and a half-inch revision survey.
236	„	„	„ two-inch original survey.
69	„	„	„ four-inch original survey.

No. 9 Party (BENGAL, BIHĀR AND ORISSA).

By Bt.-Lt.-Colonel R. H. Phillimore, D.S.O., R.E.

The party continued one-inch survey in the neighbourhood of Calcutta. Sheets 79 B/8. 11. 15, C/5. 6 were completely surveyed; sheets 79 B/12. 16, C/1. 9 were surveyed up to the limit of the forest surveys that had been made by No. 6 Party, in seasons 1906-08. Part of sheet 79 B/5 surveyed in season 1918-19, was revised, and the portion of 79 B/10 left unfinished in season 1919-20, was completed. Sheets 79 B/3. 4. 7 were commenced but could not be completed.

Work was also carried out in Bihār, sheets 72 L/1. 5. 6 being completed on the one-inch scale.

Field headquarters opened at Barrackpore on December 1st 1920, and closed on 10th May 1921. The lateness of the start was due to arrears of mapping, and also to the character of the country south of Calcutta, which does not dry up till late in December.

Personnel.

Class I Officer.

Bt.-Lt.-Col. R. H. Phillimore, D. S. O., R. E. in charge.

Class II Officers.

M . E. J. Biggie.
„ E. G. Hardinge, from 18th May 1921.
„ Amar Krishna Mitra.
Lt. C. S. McInnes, from 6th June 1921.
Mr. Bhupendra Nath Saha, M.Sc. (on probation).

Upper Subordinate Service.

Mr. Jagdeesh Prasad Vastav.
„ Amulya Charan Ghosh to 26th March 1921.
„ Gopal Lal Mitra.
„ Sasadhar Mukerjee (on probation).

Lower Subordinate Service.

29 Surveyors, etc.

The country within 20 miles of Calcutta was densely populated and well covered with trees; further south, a large area of the Sundarbans came under survey, of which the greater part had been recently reclaimed; about 270 square miles of uncleared forest were surveyed.

The whole country south of Calcutta lies below the level of the highest tides, and is intersected with a maze of tidal creeks. In areas which have been reclaimed over 50 years, there are wide swamps and *bils*, which are partly cultivated and are gradually being reclaimed by artificial drainage channels. Villages are enclosed in rich garden lands, and a thick growth of bamboos, palms, and fruit-bearing trees.

In areas more recently reclaimed, the country is covered with embankments that keep tidal water from spreading over cultivation, and the creeks which are thus cut off from the tides remain as a network of formidable obstacles, slowly silting up. Occasional sluices allow drainage to pass through these embankments. The more recently reclaimed areas are very bare of trees.

The uncleared forest areas can only be surveyed from boats; they are completely submerged by the highest spring tides, and are covered by dense jungle; though tigers and crocodiles were frequently seen, they caused only one casualty in the party; a hired boatman having his leg taken off by a crocodile when sitting in the boat.

Survey was based on theodolite traverse connected with tower stations of the Great Trigonometrical Survey.

In open areas, plane-tablers made interpolations from prominent trees and points fixed by traversers, but in congested areas a great deal of work had to be done by plane-table traversing.

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In uncleared forests plane-table traverses followed the banks of tidal creeks for considerable distances; actual chaining along the banks at low tide was very slow and terribly hard work, the mud being at least knee deep.

Some surveyors made good progress by using two small boats, with a light rope of 10 or 12 chains stretched between them.

One surveyor worked more quickly with one boat, on which he measured off two marks half a chain apart; one *khalasi* posted at the front mark, drove in a succession of bamboo poles as the boat moved along; another *khalasi* at the back mark picked the poles out and sang out to the man in front as his back mark passed the poles in succession.

Surveyors were encouraged to survey the smaller creeks by eye; it was found that distances up to 20 chains could be judged by eye with quite sufficient accuracy.

Good junction was made with the work of No. 6 Party of seasons 1906-08, although it had been impossible to connect the traverses on which the two surveys had been based. Even though rigorous chaining was impossible in the forest areas no discrepancy was found over 6 chains.

In the forest areas little change seems to have occurred during the last 15 years, except for the islands formed in the middle of rivers. Large changes were found, however, in the courses and nature of rivers and creeks in the reclaimed areas since the revenue surveys of 1850-70. These changes are due to the construction of embankments which confine the tidal waters in the streams, and cause increased deposits of silt.

Great expense was incurred in the hire of country boats for work during the season; each surveyor working in the Sundarbans area required three boats varying from 100 to 500 maunds in capacity, the larger one for the housing of himself and his squad, and the other two for survey work, and for fetching drinking water and supplies. The bill for boats amounted to Rs. 3,000 a month for the party.

For supervision by the officer in charge and camp officers the Commissioner of the Presidency Division very kindly placed his launch STELLA at the disposal of the party; the Government of Bengal were unable to spare any other launch, and the hire of suitable launches from private firms was prohibitive, the normal rate being Rs. 100 a day. With another launch the men could have been visited more frequently, and could have been helped to more rapid methods. Many of them spent far too much time surveying petty details of creeks and embankments.

Sheet 79 C/6 had to be traversed and plane-tabled simultaneously, as the traversers had been unable to reach this sheet the previous season. This work was carried out in a satisfactory manner by surveyor Hari Datta. After his theodolite traverse had been computed and plotted on return to recess, his plane-table survey was adjusted to it; the greatest error to be adjusted was 11 chains across a distance of 184 chains. His plane-table survey was carried to a direct distance of 16 miles from his initial fixed points. He measured most of his distances by subtense bar.

Health.—Work was delayed and interrupted by sickness right through the field season. Three surveyors failed to join at the beginning owing to ill health; Surveyor Khalil-ur-Rahman was only fit for light duty from the start and eventually broke down altogether; Mr. Vastav and Mr. Ghosh both suffered from ill health, and Mr. Ghosh was granted leave from March 27th.

Two *khalasis* died of cholera within a week of joining the party, and the precautions which had to be taken delayed the start of field work over a week. Six other *khalasis* died during the field season.

Surveyors kept fairly fit till the middle of March, when they began falling sick at an alarming rate. Four surveyors were on the sick list for over six weeks in March and April, from cholera, malaria, and dysentery; two surveyors were bitten by rabid animals, and had to go for treatment to the Pasteur Institute in Shillong.

Unfortunately all these casualties, except one, occurred in No. 3 Camp in the more inaccessible areas; work was greatly disorganised, for it was impossible to replace the sick men by pupils, who formed the bulk of the party.

Brackish water was a large cause of discomfort and sickness, and though surveyors were issued with water *pakhals*, *chagals* and bottles, it was difficult to keep them supplied with really fresh water, which was only found in a few well made tanks. There was a great deal of cholera amongst the villagers all over the district, and the party was really very lucky not to have more cases.

Jemadar Kashi Ram, I. M. D., Sub-Assistant Surgeon was attached to the party

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throughout the field season, and was of the utmost assistance in keeping surveyors and the camps in good health; he was continually on tour, holding inspections of personnel, distributing medicine and looking to sanitation of camps.

Plane-tabling.—Work in Bengal was divided into two camps as under:—

No. 2 Camp.—(5 trained surveyors, 1 instructor, and 9 pupils), was under Mr. J. P. Vastav, and surveyed sheets 79 B/8, C/1 and parts of 79 B/3. 4. 7, C/5.

No. 3 Camp.—(9 trained surveyors, 1 instructor and 3 pupils), was under Mr. A. C. Ghosh, and surveyed sheets 79 B/11.12.15, C/6 and parts of B/10. 16, C/5.9.

During February and March, another *Camp* (*No. 4*) was formed under Mr. G. L. Mitra, to relieve Mr. Vastav of work in sheets 79 B/3.7.

Towards the end of March, Mr. Ghosh and several of his surveyors went sick; further work in sheets 79 B/3. 4. 7 was abandoned, and Mr. G. L. Mitra took charge of No. 3 Camp.

The above work was one-inch original survey.

Three surveyors under the immediate supervision of the officer in charge were employed on the revision of sheet 79 B/5. They revised an area of 182 square miles on the one and a half-inch scale, working on blue prints of the fair sheet drawn in 1919.

Work in Bihār was under charge of Mr. E. J. Biggie as *No. 1 Camp*, which was entirely an instruction camp. Mr. Biggie with one instructor and 14 pupils surveyed an area of 703 square miles, supplementary survey on the one-inch scale, completing sheets 72 L/1. 5. 6 and doing some work in 72 L/9.

Work was carried out on blue prints of the preliminary editions, which had been compiled by the Bengal Drawing Office from recent cadastral surveys. The detail in the plains was found most accurate. Supplementary work entailed survey of hilly areas, and contouring throughout, entering relative heights, trees, and other topographical information; and revising village sites and classifying roads. The country was generally open and very easy to survey.

The average out-turn for each trained surveyor on one-inch original survey was 29 square miles a month; the average monthly out-turn for each pupil on original and supplementary surveys, one-inch scale, was 15 square miles a month.

The cost-rate for the whole detailed survey (3,000 square miles) comes to Rs. 41 a square mile. This cost-rate is very high, because two-thirds of the plane-tablers were pupils under instruction.

Traversing.—The area traversed in sheet 79 C/6 covered 120 square miles, with 89 linear miles of theodolite traverse. Practically the whole area was unreclaimed forest intersected with tidal creeks, and the traverser avoided jungle-clearing by following the banks of the creeks, using subtense bar and some triangulation, with as little chaining as possible.

Fair-mapping (in field).—One surveyor was kept at field head-quarters until end of March, working at arrears of mapping.

Recess Duties.—When the party took the field on 1st December 1920, only one sheet surveyed in 1919-20 had been submitted for publication. A section of draftsmen continued work in Shillong till December 20th, and two sheets were submitted on 10th January 1921, leaving sheets 79 B/2.6.9.13.14 still in arrears. These sheets were not completed till return to recess; the last sheet 79 B/6 will be submitted in November 1921; this sheet contains the City of Calcutta, and is very congested with detail.

The party opened fair-mapping in recess on May 16th, with 5 arrears and 14 new sheets. Of these, twelve sheets were still uncompleted on November 1st, 1921.

As the drawing strength of the party, other than pupils under instruction, numbered only 14 surveyors, ten draftsmen were attached from No. 5 Drawing Office during recess; and the sheets were double-banked right through.

There was much delay at the beginning of recess in obtaining blue prints from Calcutta; an average of 44 days elapsed from date of handing in plane-table sections in Calcutta to date of receipt of the final enlargements in Shillong. This delay was mainly due to the journeys backwards and forwards, each journey averaging 8 days and being made three times.

Fair-mapping was supervised by the following officers:—

No. 1 Section.—under Mr. E. G. Hardinge, with sheets 72 L/1. 5. 6 and 79 C/1.

No. 2 Section.—under Mr. A. K. Mitra, with arrears sheets 79 B/2.6.9.13.14 and new sheets 79 B/5.8.10.

No. 3 Section.—under Lieut. C. S. McInnes, with sheets 79 B/11.12.15.16 and 79 C/5. 6. 9.

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A small computing section under Mr. J. P. Vastav assembled the traverse records of sheets 79 A and B, and prepared data for next field season.

Training of pupils.—The party took the field in December 1920 with the following officers and pupils for instruction in plane-tabling:—

1 Class II officer.
1 Upper Subordinate officer.
6 second year pupil surveyors.
3 soldier surveyors.
19 first year pupil surveyors.

Two pupil surveyors were discharged during the field season, but the remainder did well and produced an average of 59 square miles each during the season.

One trained surveyor acted as instructor throughout the season, and two others acted for a couple of months. One instructor to every six pupils would have produced better results.

14 new pupil surveyors were appointed during June 1921 and were trained in plane-tabling on the 4-inch scale round Shillong.

During recess, 2 soldier surveyors and 8 pupils were transferred to other parties, and two more pupils were discharged.

No. 10 PARTY (UPPER BURMA).

By W. G. Jarbo.

This party continued the detail survey in Putao district and in the Hukawng valley which is unadministered and also surveyed a small portion of the tribal territory lying between the Mali Hka and 'Nmai Hka generally known as "The Triangle", the total area dealt with extending over parts of sheets 92 B/NE. SW. SE. and 92 F/NW. NE. SW. SE.

The country under survey ranges in altitude from 650 feet on the Tanai Hka to 11,000 feet at Bumhpa Bum, being for the most part covered with dense jungle. The area in the Hukawng valley comprised a level plain crossed by numerous big streams and bounded on the north and east by high hills.

The field season opened on the 30th October 1920 and closed on the 20th May 1921, but a small camp of two surveyors and an Upper Subordinate officer who had been working in Putao district from June 1920 continued work there till nearly the end of May 1921 and returned to Maymyo between the 14th and 22nd July 1921.

Personnel.

Class I Officers.

Lieut.-Colonel E. T. Rich, C. I. E., R. E., in charge from 7th December 1920 to 17th May 1921.
Captain O. Slater, M. C., R. E. (on probation).

Class II Officers.

Mr. W. G. Jarbo in charge to 6th December 1920 and from 18th May 1921.
Mr. G. E. R. Cooper.
„ H. H. Creed.
„ H. M. Critchell (on probation).

Upper Subordinate Service.

Mr. Hayat Muhammad, K. S.
„ Dhirendra Nath Saha.
„ Ram Prasad, R. S.
Maung Pe, A. T. M.

Lower Subordinate Service.

15 Surveyors, etc.

The health of the party was good.

Plane-tabling.—The total area surveyed was 3,843 square miles, all of which was done on the half-inch scale, and of this area, 1,201 square miles have been dealt with in another report.

No. 1 Camp.—Under Mr. H. H. Creed with Captain O. Slater and 11 surveyors completed an area of 2,454 square miles on the half-inch scale in sheets 92 B/NE. SW. SE. and 92 F/NW. SW. comprising a portion of the Hukawng valley.

Maung Pe, Sub-Assistant Superintendent, and surveyor Maung Po Kye, who were working independently of a camp officer, surveyed 188 square miles in the tribal territory between the Mali Hka and 'Nmai Hka known as "The Triangle" in sheets 92 F/NE SE. The former continued work in the "Triangle" till the 10th April while Maung Po Kye only worked there till the end of January and then joined No. 1 Camp, both having been recalled at the instance of the political authorities as it was feared that they might become involved in some of the inter-tribal feuds.

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The cost-rate of half-inch original survey is Rs. 33·5 per square mile, and is higher than that of last year, which was Rs. 27·2 per square mile for the same scale of survey.

Triangulation.—Triangulation in advance for detail survey on the half-inch scale was carried out in sheets 83 N/NW. NE. SW. SE. and 92 A/SW. SE.

Mr. Hayat Muhammad triangulated for detail survey on the half-inch scale in sheets 92 A/SW. SE. and Mr. Ram Prasad in 83 N/NW. NE. SW. SE.

The area triangulated embraced the northern portion of the Hukawng and also a part of the unadministered area to the west of the Upper Chindwin district which is inhabited chiefly by Nāgās.

The cost-rate of the triangulation is Rs. 16·2 per square mile, which is much higher than that of last year which was Rs. 6·4 per square mile. This is due largely to the very high rate of wage of the coolies and to the great cost of transport of the rations of Mr. Hayat Muhammad and his men in the Hukawng.

Five pupils of the party were under instruction. The cost of the instruction camp was Rs. 16,357.

Recess Duties.—(*a*) The fair-mapping of the party was under the charge of Mr. H.H. Creed till the arrival of Mr. G. E. R. Cooper on the 22nd July, after which it was divided into two sections.

No. 1 Section.—Under Mr. G. E. R. Cooper with Maung Pe and 6 draftsmen completed the fair-mapping of 2,217 square miles in sheets 92 I/NW.SW.SE. These three sheets will be submitted for publication before the party takes the field.

No. 2 Section.—Under Mr. H. H. Creed with Mr. H. M. Critchell and 8 surveyors completed the fair-mapping of 2,294 square miles in sheets 91 H/12 and 91 H/7.8, 92 C/2.5.9.13, 92 G/1, 92 E/NW. and A/NE., 92 E/SW. and A/SE., 91 H/SW.SE., 91 L/SW., 92 E/SE., 92 F/NW.SW. and 92 I/NE., all of which will have been submitted before the 1st November 1921.

(*b*) The computations of the season's triangulation were carried out by Messrs. Hayat Muhammad, K. S., and Ram Prasad, R. S., and completed.

Inspections.—The Surveyor General and Superintendent, Eastern Circle, inspected the party during recess.

No. 11 PARTY (LOWER BURMA).

By Captain T. M. M. Penney, R. E.

The field programme of the party was as follows:—

(*a*) Continuation of the topographical programme on the one-inch scale in the district of Mergui, Lower Burma.

(*b*) Traversing of the boundaries of five reserved forests in the Ataran Forest Division in the Amherst district and supplementary triangulation of existing work to give points on which to base the traverses.

(*c*) The completion of the triangulation in the Mergui district to Victoria Point and the connection of this to the Siamese work along the administrative boundary and the revision and supplementing of last year's work.

PERSONNEL.

Class I Officers.

Mr. J. O. Greiff, in charge to 30th June 1921.
Captain T. M. M. Penney (on probation) attached from 3rd May 1921 and in charge from 1st July 1921.

Class II Officers.

Mr. O. J. H. Hart.
" F. C. Saint to 3rd March 1921.
" F. J. Grice from 14th October 1920.
" A. V. Dickson from 5th February 1921.

Upper Subordinate Service.

Mr. Pratul Chandra Sen Gupta, B. Sc.
" Khan Muhammad from 1st April 1921.

Lower Subordinate Service.

31 Surveyors, etc.

The nature of the country surveyed in the Mergui district has already been alluded to in previous reports and the same dense jungle stretching over steep hills and deep valleys, the same mosquito and sandfly infested mangrove swamps and the entire absence of roads and lack of habitations were encountered this year.

The area surveyed comprised the head waters of the Ngawun river, the upper reaches

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of the Lenya, the basin of the Klohng Kathom, the land lying between the Lenya and the sea and one area consisting practically entirely of mangrove swamps and long tidal creeks.

The whole area is densely wooded, not only with forests, trees of great girth and height, but with tangled scrub and creeper jungle which greatly augmented the difficulties usually encountered in a country possessing no communications and few inhabitants. Some idea may be gathered of the immensity of the trees when it is pointed out that a *machan* on the banks of the Ngawun was 167 feet above the ground and at least 12 feet from the top of the tree; this one only just happened to be measured not that it was in anyway taller or grander than any of its surrounding fellow giants. The greater portion of this area is uninhabited—there being only a few fishing villages along the coast and one or two along the banks of the Lenya. Much of it is waterlogged marsh and swamp, in which, as well as in the streams, along the beds of which was often the only route that could be followed, were countless leeches—the only protection against which were linen socks or stockings and whose close companionship was an additional source of inconvenience to the traveller.

The Ngawun Chaung in its upper reaches is in parts a torrent rushing over falls and rocks and forming deep dark pools of clear water. Every step of the way into the interior had to be cleared, and often the water in streams along which one had to wade was well above the knee. The Lenya river is a large tidal stream navigable for large country boats and shallow draft launches up to the village of Lenya.

The eastern boundary of the area surveyed was the administrative boundary between Burma and Siam which follows the watershed dividing the waters of the Bay of Bengal from those of the Gulf of Siam. Though this is a clearly defined ridge line, the hill features falling away from it and rising again to the west to form the watershed between the Ngawun and the Lenya are so broken and irregular, so densely wooded and so cut up with streams and water courses that plane-table fixings were a difficult and lengthy process on account of the amount of clearing required and the plane-table traversing that often had to be resorted to is at all times a very slow method of work. The seaboard areas were in dense mangrove swamp and the only method of work was to carry out plane-table traverses in boats up and down the numerous creeks by which the mangrove swamps are intersected.

The whole of this area with the exception of the south-western portion was *terra incognita* and had never been mapped before, in the south and western portions old one-inch maps published about 1890 were available.

The area triangulated was very much the same sort of country but towards Victoria Point the jungle is not so dense and a mule road exists between Victoria Point and Maliwun and Marang.

The area in which the triangulation and traversing were done in the Amherst district was mostly flat forest and cultivation-covered land, but, in one portion, where four triangulation stations had to be established, there is a remarkable pinnacled outcrop of rock rising from 500 to 1,200 feet, the ascent of which was impossible except with the use of ladders; in one instance 26 ladders totalling a length of nearly 600 feet had to be employed, which rendered the formation of triangulation stations both difficult and dangerous. There is a steamer service on the Ataran river connecting the surrounding country with Moulmein, and a motor service on the Moulmein-Amherst road.

It was impossible to complete the programme of detail survey in the Mergui district for the following reasons:—

Only twelve experienced surveyors were available whose out-turn was very good and not below the average, being 24 square miles per man per month.

The three pupils with training at Maymyo and one season in the field at Syriam were quite at sea in the difficult Mergui district and not till the end of the season did they seem to be able to master the difficulties of the local terrain. Abnormal bad weather which started about 20th April continued right through May and the rainfall during the preced-

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ing months was quite exceptional, seven days continuous rain occurring in December, which flooded all the streams and upset many arrangements and caused the unavoidable and heavy loss of twenty-five mules.

The roads towards the Siam boundary which had to be cut, proved extraordinarily difficult and troublesome, and to move a surveyor from one bit of ground to another to help one who might be behindhand proved to be almost impossible.

The field season headquarters opened in Mergui on the 16th November 1920 and closed on 21st June 1921.

The health of the party was good on the whole, two khalasis died of sickness in Mergui, but the end of the field season was clouded by the outrageous murder of 1st class surveyor Abdush Shakur, who was wantonly done to death by his own tindal and khalasis within two days of the completion of his work, a dastardly crime, which had been planned a month before solely because the surveyor could abide by no laziness on the part of his menials and expected them to show the same spirit of conscientious hard work as he did himself.

The party was most unfortunate during the recess season. One 1st class surveyor and one draftsman took seriously ill and were recommended for long leave on medical certificate and also the party suffered the loss of 1st class surveyor Partab Singh who took suddenly ill and died within 24 hours. His death will be a great loss to the party.

Plane-tabling.—The field work was divided up into two camps :—

No. 1 Camp.—Mr. Hart in charge, with seven surveyors formed No. 1 Camp with headquarters at Lenya, and surveyed an area of 694 square miles in sheets 96 M/3. 7 and parts of I/15.16 and M/4.

The hospital was under the control of this camp throughout the season.

No. 2 Camp.—Mr. Grice in charge, with four surveyors and three pupils, formed No. 2 Camp with headquarters at Bokpyin and surveyed an area of 530 square miles in sheets 96 I/11. 15. 16 and M/4.

Surveyor Muhammad Din surveyed under the direct control of the Executive Officer an area of 270 square miles in sheets 96 I/9 and I/5.

The cost-rate is as follows :—

Original one-inch.....Rs. 98·79 per square mile.

The cost-rate is of course much affected by the increase of pay and allowances which have been given throughout the department.

Pupils who were employed in the Mergui district cost as much for their squads and mules and contingencies as any other surveyor and the out-turn of the three pupils was only 75 square miles in all. The Mergui district owing to the necessary heavy expenditure involved in its survey and the difficulties encountered is quite unsuitable for the employment of pupils who can receive their training at less cost in some easier and less expensive country.

Triangulation.—Triangulation was executed by Mr. Khan Muhammad in sheets 96 J/1. 2. 5. 6. 8. 9. 10. 11. 12. 13. 14. 15 and K/9 covering an area of 2,012 square miles, including 355 square miles of sea-area and revision of last year's work. The work to the south was new work but he also revised and supplemented with additional points the triangulation that had been carried out the previous season. One station and an intersected point of the Siamese work were utilised as stations and four other Siamese stations were intersected. The exact position of the one mutual station could not be discovered as there was no definite mark-stone found, so it cannot be said that any real connection was established with the Siamese triangulation. The statement below shows the comparative values as obtained by Mr. Khan Muhammad and the Survey of Siam.

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Comparison of the Values of Stations common between Mr. Khan Muhammad's and Siamese triangulation, Season 1920-21.

List of Latitudes, Longitudes and Heights of Trigonometrical Stations and Points.

(Siamese triangulation values are printed in Roman figures, and Mr. Khan Muhammad's values in Italic figures).

Name of Station or Point.		Latitude.	Longitude.	Height in feet.		
		° ′ ″	° ′ ″			
Khao Den frontier hill 891 R.	Signal	10 49 37·41	98 59 58·90	1751·5	*	
	H.S.	*10 49 38·22*	*98 59 59·08*	*1780 8*	*gr.*	*H.S.*
Khao Den frontier hill 893 R.	S gnal	10 56 0·90	99 0 23·60	1464·8	*	
	Intersected point	*10 56 1·61*	*99 0 23·70*	*1539·2*	*T.*	*Intersected point.*
Khao Sung ...	H.S.	10 58 36·55	99 8 35·18	2595·9	*	
	Tree. Intersected point.	*10 58 37·67*	*99 8 36·27*	*2634·2*	*T.*	*do.*
Khao-Tejyei ...	H.S.	11 14 18·23	99 18 14·75	2938·8	*	
	H.S.	*11 14 18·58*	*99 18 14·78*	*2976 3*	*gr.*	*do.*
Khao H. Mark ...	*Intersected point*	11 3 31·60	99 11 2·90	2169·7	*	
	H.S.	*11 3 32·69*	*99 11 2 83*	*2196 8*	*gr.*	*H.S.*
Khao-Ptai-glohng ...	Signal	10 41 5·30	98 54 50·90	2235·6	*	
	Topo. point	*10 41 6·49*	*98 54 50·62*	*2283·9*	*gr.*	*Intersected point.*

* There is no mention to which part of a signal the heights are referable.
gr.—indicates ground. T.— indicates top of tree.

The cost-rate is as follows :—

One-inch Triangulation and Computation...Rs. 15·57 per square mile.

The triangulation is considerably cheaper than last year and credit is due to Mr. Khan Muhammad newly appointed as an Upper Subordinate for the efficient manner in which it was carried out.

Traversing.—No. 3 Camp.—Mr. Sen Gupta in charge, with two traversers and two pupil traversers, formed No. 3 Camp and completed the boundary traverse of five forest reserves as well as the supplementary triangulation on which the traverses were based, covering an area of approximately 327 square miles and 275 linear miles of traversing in sheets 94 H/11. 12. 15. 16, L/4 and portion of 95 E/9. 13.

Recess Duties.—(*a*) In recess the fair-mapping of the party was divided into two sections :—

No. 1 Section.—Under the charge of Mr. Grice employed on the fair-mapping of sheets 96 I/15 and M/4.7.

No. 2 Section.—Under the charge of Mr. Dickson employed on the fair-mapping of sheets 96 I/9.11 and M/3.

Drawing Office Section.—Besides the above, a Drawing Office was maintained at Maymyo throughout the field season under the charge of Mr. Saint till 4th March 1921, when he proceeded on leave and was succeeded by Mr. Dickson. It was employed on the fair-mapping of the following sheets :—93 O/SW., P/NW., P/SW., P/SE., P/NE., 95 J/SW., J/SE., K/NE., F/NE., F/SE., K/SW., and 102 D/NE., D/NW., D/SW., G/NW., G/SW., on the half-inch scale and the following sheets : 96 M/2, I/6, I/14, and 93 I/14 on the one-inch scale.

11 were despatched for publication, 6 sent to No. 5 Drawing Office for completion and the other three will be completed by the Maymyo Drawing Office in due course.

During the year under report, the following sheets have been submitted for publication: 95 J/SW., K/SW., F/SE., 102 D/NW., D/NE., D/SW., G/SW., on the half-inch scale and 96 M/2, M/6, I/14. I/13, I/6, 93 I/14 and 96 I/9 on the one-inch scale, the last one being this season's field work; sheet 96 M/7 is also completed and will be despatched as soon as

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the plane-tables are available from the drawing of sheets 96 M/3 and M/4 which two sheets together with sheets 96 I/11 and I/15 will be ready for despatch by the end of October 1921; this will again mean that the party has no arrears of mapping.

(*b*) *No. 3 Section.*—Under the charge of Mr. Gupta comprised the computing section and carried out the computations of the triangulation of Mr. Khan Muhammad in Mergui district and the triangulation and traversing in the Amherst area.

The computations of the triangulation have been completed and those of the forest boundaries will be completed a month before the party takes the field.

Miscellaneous.—The most difficult problem in connection with the field work was the regular supply of provisions to the several camps and surveyors scattered over a large area conspicuous for the absence of roads. All supplies had to be sent from Mergui by boats and sent up from the camps by mules. The early loss of a large number of mules, due to unprecedented bad weather as already mentioned, greatly increased these supply difficulties and bad weather hampered the progress of the country boats employed round the coast by the surveyors and for the carriage of rations. Sandflies along the coast and lack of suitable camping grounds, the denseness and impenetrability of the jungle and the exceptional rainfall all contributed to making the field season a trying and arduous one.

Inspections.—The party was inspected in the field by the Superintendent, Eastern Circle between 1st and 7th February 1921 and in recess by the Surveyor General on 2nd August 1921. The Drawing Office at Maymyo was inspected by the Surveyor General on the 24th January 1921 and by the Superintendent, Eastern Circle on 6th and 7th December 1920 and 24th January and 18th May 1921.

No. 12 PARTY (ASSAM).

By Bt.-Lt.-Colonel C. M. Browne, C. M. G., D. S. O., R. E.

The party carried out detail survey on the scales of 2 inches and ½ inch = 1 mile and triangulation and traversing in the districts of Cāchār, Nowgong, Khāsi and Jaintiā Hills, Nāgā Hills, Sibsāgar and in Manipur State. The country consisted partly of plains and partly of low hills in Nowgong and Sibsāgar and of hills, mostly densely wooded, with occasional grass areas in the other districts.

The field season extended over a period of 6½ months from 5th November to the 20th May. The health of the party was not very good; in spite of the provision of mosquito nets for all surveyors, there was a good deal of malarial fever. One clerk died of pneumonia, one surveyor was bitten by a rabid dog, 5 khalasis were killed by man-eating tigers, 2 others died of pneumonia and Abbas Ali tindal died of natural causes (he had very long service).

Personnel.

Class I Officers.

Major F. B. Scott, I. A., in charge up to 3rd November 1920.
Bt.-Lt.-Col. C. M. Browne, C. M. G., D. S. O., R. E., in charge from 4th November 1920.

Class II Officers.

Mr. E. M. Kenny.
„ D. K. Rennick, M. B. E.
„ Prafulla Chandra Mitra, B. A.

Upper Subordinate Service.

Mr. Girija Sonker Bagchi.

Lower Subordinate Service.

31 Surveyors, etc.

Plane-tabling.—The country surveyed was mostly dense jungle with scattered villages and patches of cultivation intersected by rivers, which for a great part run in deep gorges. Coolies are the only means of transport, supplies were difficult to obtain and expensive. The major portion of the work being on the half-inch scale, supervising officers had to cover a lot of ground in order to examine the work of the surveyors. As walking was the only means of conveyance, it was difficult properly to supervise the work of many surveyors under these conditions. In a great part of the area under survey, chaining had to be employed and the advantages of the half-inch scale were lost; in fact, if a surveyor has to work with a chain, it is probably more difficult to work on the half-inch than on the one-inch scale.

The party was divided into two camps:—

No. 1 Camp.—Headquarters Khorungma, under Mr. E. M. Kenny with 11 surveyors and 1 pupil, surveyed 1,041 square miles of original survey on the ½-inch scale and 116 square miles of reserved forests on the 2-inch scale in parts of sheets 83 C/NE. SE.

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No. 2 Camp.—Headquarters Baitha-langso, under Mr. P. C. Mitra with 10 surveyors, surveyed 1,592 square miles on the ½-inch scale and 17 square miles of reserved forest on the 2-inch scale. Work in the plains and low hills was carried out by plane-table traversing based on theodolite traverses and in the hills by interpolation.

Triangulation.—Triangulation was carried out by Mr. D. K. Rennick in sheets 83 G/3. 4. 6. 7. 8. 10. 11. 12. 13. 14. 15 and by Mr. G. S. Bagchi in sheets 83 G/1. 5. The country was mostly densely wooded, hills rising to about 9,000 feet; a large amount of jungle clearing was necessary and labour and supplies were difficult to obtain. Rain and cloud in the months of April and May and dust haze in the months of February and March greatly interfered with the observations.

Traversing.—Traversing was carried out along the boundaries of and within reserved forests in sheets 83 C/14, 83 G/1. 2. 5. 6. 9. 10. 13 and, in addition, traverse lines were run for detail survey in other plain portions of the same sheets. 4 traversers were employed. The area is unhealthy and transport difficult to obtain. The deuse jungle makes the work slow and laborious and, in parts, even water was difficult to get. Most of the traversers suffered from malaria, the out-turn is consequently rather small and the cost-rate high.

326 linear miles were traversed, covering an area of 248 square miles: 3,490 stations were observed at, of which 58 can be considered as permanent.

Recess Duties.—(*a*) The fair-mapping was divided into three sections at first, but, on Mr. Mitra going on privilege leave, his section was amalgamated with that of Mr. Kenny.

No. 1 Section, under Mr. E. M. Kenny, carried out the fair-mapping of sheets 83 C/NW. NE. SW. SE. on the half-inch scale, part of 83 C/SE. and the major part of 83 C/SW. having been drawn in recess season 1920.

No. 2 Section, under Mr. D. K. Rennick, carried out the fair-mapping of the following reserve forests on the 2-inch scale:—Rangkhang, Hojai, Habaipur, Barpāni, Krungming, Saipung, Narpuh block No. I, Narpuh block No. II, Barail and Cāchār (the latter in two sheets), all from original surveys of season 1919-20 or 1920-21.

The innovation, as far as this party is concerned, of the party drawing its own forest sheets was very successful; draftsmen not practised enough for the half-inch fair sheets can be employed and it is very good practice for them. Much drawing can also be done in the early part of recess pending the return of some of the blue prints from Calcutta, in which inevitable delay takes place.

(*b*) Mr. G. S. Bagchi, 3 computers and 3 traversers completed the computations of the triangulation and traversing done during the last field season and the four-inch boundary plots of artificial boundaries of the following reserve forests have been completed and will be submitted—Krungming, Hojai, Rangkhang and Habaipur. There are no boundary plots in arrears except those for survey 1921-22 which will be drawn and submitted when the survey is complete.

Miscellaneous.—Surveyor Singh Bir Thapa was working in sheet 83 C/12 in the area reported deserted in last year's report. All went well till the work was nearly finished and he was near the deserted village of Rymphing in the beginning of February, when no less than five of his *khalasis* were killed by man-eating tigers within a few days. Lt.-Col. Browne, and Mr. E. M. Kenny, proceeded there with two elephants, rescued most of the kit and enabled the surveyor to complete the work.

Singh Bir Thapa for his exemplary conduct and devotion to duty on this occasion was awarded a Certificate of Honour and an honorarium of Rs. 100, the former was presented to him by the Superintendent, Eastern Circle at a durbar held at Shillong on 18th September 1921.

The party's elephants were of great assistance in Cāchār and Nowgong districts; rice and supplies had to be carried to the surveyors in the forests, etc.

Inspections.—The Surveyor General inspected the party on 30th August 1921. The Superintendent, Eastern Circle inspected the party in the field in March 1921 and frequently in recess. The Superintendent, Map Publication visited the party on 22nd June 1921.

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No. 21 (BURMA FOREST) PARTY.

By S. F. Norman.

This party continued detail forest surveys on the 4-inch and 2-inch scales in Upper Burma and the Shan States in sheets 83 P/9.10.13.14 and 93 D/1.5.6.9.10 and triangulated and traversed an area of 405 square miles in Lower Burma. The country over which operations were carried out consists of well wooded hills ranging in altitude from 200 to 3,500 and 5,000 feet.

The field season covered a period of about 7 months, commencing from 20th November 1920 and closing on different dates between 25th May and 25th June 1921.

The health of the members of the party in the field was not good. There were several deaths among the menial staff. Four kachins succumbed to pneumonia, 5 Hazāribāgh khalasis died of malaria fever. One pupil surveyor, Maung San Shin, also died of fever.

PERSONNEL.

Class I Officer.

Mr. H. W. Biggie, in charge up to 18th July 1921.

Class II Officers.

Mr. S. F. Norman, joined 25th October 1920; in charge, from 19th July 1921.

Lieut. L. B. Fitz-Gibbon, joined 16th November 1920, in charge, Survey Training School.

Capt. V. P. Wainright, from 28th October 1920.

Capt. C. B. Sexton, from 14th March 1921.

Mr. H. M. Critchell, (on probation) from 25th October 1920 to 2 th June 1921.

Upper Subordinate Service.

Mr. Dalbir Rai. attached to Survey Training School.

„ Ghulam Hasan, from 6th November 1920.

„ Bhamba Ram, up to 10th July 1921.

Lower Subordinate Service.

14 Surveyors, etc.

Plane-tabling.—(*a*) (*Northern Forest Circle*).—The total area surveyed on the 4-inch scale was 44,032 acres (69 square miles) at a cost-rate of Rs. 532·7 per square mile. This included the reserve of Hwelit and parts of Mode and Chaunggyibya Reserves.

No. II Camp, under Mr. Ghulam Hasan, with three surveyors and 2 pupils, completed an area of 32·8 square miles in Hwelit, Chaunggyibya and Mode Reserves in sheets 83 P/9.10.14. 19·9 linear miles of test lines were run and the work was also tested from 280 *in situ* fixings by Messrs. Biggie, Norman and Ghulam Hasan.

No. III Camp, under Mr. Bhamba Ram with Mr. Critchell and 4 surveyors, completed an area of 36·0 square miles in Mode, in sheets 83 P/9.13. The accuracy of the work was tested by 15·3 linear miles of chaining and 222 *in situ* fixings by both Messrs. Biggie and Bhamba Ram.

The average monthly out-turn per man on this scale was only 1·3 square miles, due partly to the prevalence of malarial fever, and partly to the difficulty experienced in surveying with chain and compass; interpolation being practically impossible.

The Mode Reserve area comprises parallel ranges of hills bearing north-north-east and south-south-west covered with dense forest intersected by several large streams and very broken in the north and south, with ragged knife-edged cliffs rising to an altitude of 3,600 feet.

Work in the Hwelit and Chaunggyibya areas was not quite so laborious but the thickly clad and intricate nature of the ground presented many difficulties.

(*b*) *Southern Forest Circle.*—In the Meiktila and Southern Shan States Forest Divisions, areas of 28,864 acres (45 square miles) and 37,248 acres (58 square miles) respectively, of the following reserves:—Yupadaung, Wetpyuye and Ye-E completely and Magwe in part, falling in sheets 93 D/1.5.6.9.10, were surveyed on the two-inch scale.

No. I Camp of 5 surveyors and one pupil, under Mr. Norman up to 31st March 1921 and thereafter under Captain Sexton, completed the area by 25th May 1921. The average out-turn per man per month was 3·6 square miles. The work was thoroughly tested by the two camp officers, 29·5 linear miles of test lines were run, and the detail further checked from 103 *in situ* fixings.

The country surveyed was of a varied nature. The Yupadaung Reserve lying along the foot hills, comprises a good deal of low-lying flat uninteresting country, covered for the most part with clumps of bamboos and stunted tree growth, and ranges in altitude from 500 to 3,500 feet. The Magwe, Wetpyuye and Ye-E reserves, occupying the uplands and bordering on the boundary between Burma proper and the Shan States, are chiefly pine-clad in the higher ranges, and densely wooded in the valleys. They range in altitude from 1,000 to 5,000 feet, and the main road from Thazi to Taunggyi divides the area longitudinally into the two large blocks which constitute the reserves.

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Triangulation.—Minor triangulation was carried out by Captain Wainright in the Bassein Forest Division, Delta Forest Circle, in sheets 85 K/11. 12. 14. 15. 16 and 85 L/9. 3 of 405 square miles. 12 new stations were built and 4 old ones visited and re-observed at, and in addition 32 intersected points were fixed.

The triangulation was started from the base Letkôk, Mogyuttaung H.S. of the Secondary Triangulation, executed by the Burma Party between 1875 and 1881, and closed on the base Kyôndôn H.S.–Kyauktalôn H.S. of the same series. The area triangulated over consisted of dense bamboo and timber forest, which necessitated very heavy clearing. The country is very little known, has no roads or tracts, and the only means of getting through the forests was by following the main streams.

Traversing.—The area traversed lies in all the sheets mentioned above and covers an area of 245 square miles comprising the following reserves:—Podaw, Kyeintali, Sitsayan, Shwemyindin, Kungyaung and Kyetpaung. In the latter two, the traverses are incomplete as work here had to be postponed owing to *khedda* operations. A camp of one traverser and 4 pupils under Captain Wainright completed the traversing of 186·3 linear miles by 31st May 1921.

Recess Duties.—(*a*) The fair-mapping for the season comprises the following reserves:—Mode, Chaunggyibya, Hwelit, Yupadaung, Magwe, Wetpyuye and Ye-E in 7 sheets; 5 on the four-inch scale and 2 on the two-inch scale.

The drawing section under Captain Sexton, with the assistance of Mr. Ghulam Hasan and 7 draftsmen, completed and submitted 3 sheets for publication, the remainder being well in hand.

(*b*) Captain Wainright with the assistance of 5 computers has completed the computations of the triangulation and traversing of the forests in the Bassein Forest Division, which are to be surveyed in 1921-22.

The cost-rate for computations is Rs. 17 per square mile.

Miscellaneous.—A small item of survey, viz., the re-alignment of a boundary to decide a dispute between two states was asked for by the Political Officer, Southern Shan States, and this was done by Capt. Sexton; as also the testing and correction of the transferred alignment of the Southern Shan States Railway on the old one-inch maps of the Survey of India.

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TABLE I.
OUT-TURNS OF PLANE-TABLING 1920-21.

Scale.	Class of survey.	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
¼-inch	Revision Survey	N	No. 1	Simla Hill States. Kāngra district and Chamba State	159	239·0	0·1	...
½-inch	Original Survey	N	No. 1	Simla Hill States, Kāngra district and Chamba State	465	135·7	0·8	...
		N	No. 2	Rājputāna and United Provinces	1,059	62·5	4·3	6·6
		E	No. 10	Upper Burma	3,843	58·6	0·4	2·5
		E	No. 12	Assam	2,633	36·8	3·1	2·8
½-inch	Revision Survey	N	No. 1	Simla Hill States, Kāngra district and Chamba State	2,365	38·8 (*a*)	1·2	...
1-inch	Original Survey	N	No. 1	Simla Hill States, Kāngra district and Chamba State	359	56·4	3·5	...
		N	No. 3	Nepāl	60	30·0	8·8	...
		S	No. 5	Berār, Bombay, Central India and Central Provinces	2,768	25·3	8·0	2·0
		S	No. 7	Madras	3,383	36·0	9·5	0·4
		S	No. 8	Madras and Travancore State	303	18·7	5·8	1·2
		E	No. 9	Bengal	1,187(*b*)	28·9	4·0	10·0
		E	No. 9	Bengal	928(*c*)	15·0	10·0	25·0
		E	No. 11	Lower Burma	1,494	20·0	1·0	4·8
1-inch	Re-survey	N	No. 2	United Provinces	286	33·3 (*b*)	11·5(*b*)	5·0 (*b*)
		N	No. 2	United Provinces and Rājputāna	1,407	17·7 (*c*)	16·6 (*c*)	8·1 (*c*)
1-inch	Revision Survey	N	No. 1	Simla Hill States, Kāngra district and Chamba State	5,052	30·1	3·4	...
		N	No. 2	United Provinces	1,208	39·2	6·9	4·9
		N	No. 3	Do.	610	32·4	3·4	4·9
	Supplementary Survey	S	No. 5	Berār and Central Provinces	1,103	37·4	2·7	2·9
1-inch	Revision Survey	S	No. 7	Madras and Mysore	727	210·3	0·5	...
1-inch	Supplementary Survey	S	No. 7	Madras	440	47·1	5·6	...
		S	No. 8	Do.	4,810	28·0	6·2	2·6
		E	No. 9	Bihār and Orissa	703(*c*)	15·2	8·0	2·0

(*a*) An average number of 7 pupil surveyors was also employed on 1-inch and ½-inch revision throughout the season and this has brought down the average out-turn.

(*b*) By trained surveyors. (*c*) By pupils.

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TABLE I.—*Concluded.*

OUT-TURNS OF PLANE-TABLING 1920-21.—*Concluded.*

Scale.	Class of survey.	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
1½-inch	Revision Survey	E	No. 9	Bengal	182 (*b*)	28·7	1·0	18·0
2-inch	Original Survey	N	No. 3	United Provinces and Tehrī-Garhwāl	1,247	10·3	15·5	0·9
		S	No. 7	Madras	628	10·0	26·5	4·3
		S	No. 8	Do.	43	10·5	18·4	2·8
		E	No. 12	Assam	133	6·7	11·9	31·8
		E	No. 21 (Burma Forest)	Upper Burma	103	3·6	10·0	79·0
2-inch	Supplementary Survey	S	No. 7	Madras	65	12·8	16·6	6·8
		S	No. 8	Do.	5	5·5	20·3	...
4-inch	Original Survey	E	No. 21 (Burma Forest)	Upper Burma	69	1·3	..	294·0
4-inch	Revision Survey	N	No. 2	Delhi Province	134	14·7	12·8	9·8
8-inch	Large Scale Survey	N	No. 1	N. W. Frontier (Doāba Cantonment)	13½	1·2	449·0	...
					acres.	acres.	acres.	acres.
16-inch	Original Survey	S	No. 20	Velichi military land west hill	316			
					116			
				Wellington and military lands	5,101	351·6	0·2	1·6
				Bangalore Civil and Military Station and Bangalore Grass Farm	3,578			
16-inch	Revision Survey	S	No. 20	Bangalore Civil and Military Station	5,583	298·4	0·1	2·9
64-inch	Original Survey	S	No 20	Cannanore	27·0			
				Poonamallee	27·3	40·7	...	12·0
				St. Thomas's Mount	229·2			
50-feet	Original Survey	S	No. 20	Bangalore Civil and Military Station	489·4	13·3	...	22·0

(*b*) By trained surveyors.

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TABLE II.

DETAILS OF TRIANGULATION AND TRAVERSING 1920-21.

Scale.	Class of survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	Stations.			Intersected Points.		Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
									Number of stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Number of intersected points fixed.	Linear error per mile in feet.					
1-inch	Original Survey	N	No. 1	Tehrī State, United Provinces	5	2,400	3·7	3·7	48	3·8	0·25	600	2·19	...	...	...	...	...
1-inch	Ditto	N	No. 2	Central India, Rājputāna and U. P.	...	...	...	...	...	...	...	...	...	527	423	1,127	5·3	1·4
64-inch	Ditto	N	No. 2	United Provinces	...	...	...	...	...	...	...	...	...	6·45	129	2,259	4·0	0·16
2-inch	Ditto	N	No. 3	U. P. and Nepāl	5	1,280	1·4	1·4	50	6·1	0·13	862	0·38	59·9	44·2	(Traverse rejected)		
½-inch	Ditto	S	No. 5	Central India and Central Provinces	6	2,199	13·1	13·7	20	14·3	0·51	148	0·64	...	...	...	...	...
½-inch	Supplementary Survey	S	No. 6	Amrābād R. F. (Mahbūbnagar District) Hyderābād (Deccan)	6	670	2·5	1·2	44	9·1	0·25	225	0·42	...	..	...	...	...
16-inch	Original Survey	S	No. 20	Deolāli	6	56	1·7	...	14	15·5	0·61	18	0·72	...	16·26*	76	3·9	0·1
16-inch	Ditto	S	No. 20	Bangalore Civil and Military Station	6	...	...	...	...	...	...	...	...	...	72·60*	768	5·0	0·3
16-inch	Revision Survey	S	No. 20	Ditto	6	...	...	...	...	...	...	...	...	...	22·13*	191	1·4	0·2

* These figures include 50·88 linear miles levelling.

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TABLE II.—*Concluded.*

DETAILS OF TRIANGULATION AND TRAVERSING 1920-21.—*Concluded.*

Scale.	Class of survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	Stations.			Intersected Points.		Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
									Number of stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Number of intersected points fixed.	Linear error per mile in feet.					
1-inch .	Traversing .	E	No. 9	Bengal .	...	...	...	...	...	...	...	...	...	120	89	244	0·5	0·6
½-inch .	Original Survey .	E	No. 10	Upper Burma .	6	1,411	18·6	18·6	6	7·1	0·15	70	0·45	...	...	...	...	...
½-inch .	Ditto .	E	No. 10	Do. .	6	2,183	12·3	12·5	12	7·2	0·27	165	0·38	...	...	...	...	...
1-inch .	Ditto .	E	No. 11	Lower Burma .	6	3,309	18·6	18·6	26	10·6	0·34	150	6·68	...	...	...	...	...
2-inch .	Ditto .	E	No. 11	Do. .	...	...	...	...	...	...	...	...	...	327	275	4,619	5·3	...
½-inch and 1-inch	Triangulation .	E	No. 12	Assam .	6	2,752	11·5	18·6	27	8·7	0·54	210	0·16	...	...	...	...	...
½-inch, 1-inch and 2-inch	Traversing .	E	No. 12	Do. .	5	...	...	...	...	...	...	...	...	248	326	3,490	3·1	1·4
2-inch .	Original Survey .	E	No. 21 (Burma Forest)	Burma .	6	405	8·4	9·4	16	9·5	1·67	32	11·60	245	186	4,846	...	...

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TABLE III.

COST-RATES OF SURVEY 1920-21.

Circle.	Party.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.																	COST-RATES, RUPEES.				Total plane-tabling out-turns on all scales, square miles.	Total cost of party.	Remarks.
			½-, ⅓-, & 1-inch	¼- & 1-inch	½-inch	1-inch				1½-inch	2-inch		4-inch		8-inch	16-inch		64-inch	50-feet	Triangulation per square mile.	Traversing per linear mile.		Fair-mapping, per square mile.			
			Revision survey.	Original survey.	Original survey.	Original survey.	Re-survey.	Revision survey.	Supplementary survey.	Revision survey.	Original survey.	Supplementary survey.	Original survey.	Revision survey.	Military survey.	Original survey.	Revision survey.	Original survey.	Original survey.		Topographical.	Forest boundary.				
N	No. 1	Simla Hill States, Kāngra district and Chamba State ...	14·2	9·2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·2 (*c*)	8,413½	1,84,175	
N	No. 1	Tehrī State ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8·1	...	...	13·5 (*d*)			
N	No. 1	Mussoorie and Landour	...	...	...	...	...	..	...	...	..	...	...	...	...	...	..	...	...	...	...	...	494·8 (*m*)			
N	No. 1	Doāba Cantonment, N.W. Frontier ...	35	...	...	...	...	...	...	...	...	...	...	...	340·2	...	...	...	...	...	...	...	...			
N	No. 2	Central India, Delhi Province, Rājputāna, and United Provinces	...	...	12·1	...	15·7	12·8	...	...	...	...	...	45·1	...	...	...	...	...	...	16·0(*a*) 61·5(*b*)	...	6·3 (*c*) 3·2 (*d*) 15·0 (*e*)	4,094	1,54,117*	* Includes Rs. 7,933 debitable to Allahābād Improvement Trust.
N	No. 3	United Provinces, Tehrī State Garhwāl and Nepāl ...	...	...	...	17·3	...	22·4	...	...	53·8	...	...	...	...	...	...	...	...	12·5⊙	14·8⊙	...	22·2 (*g*) 6·6 (*c*)	1,917	1,53,408†	† Excludes cost of traverse which was rejected.
S	No. 5	Bombay, Central India and Central Provinces	...	...	...	19·8	...	...	13·4	...	...	...	...	...	...	...	...	...	...	3·8	...	...	9·0	3,871	1,13,130	⊙ Including computations.
S	No. 6	.. ..	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	54·6	...	...	139·0 (*e*) 41·2(*f*) 66·1 (*g*) 18·5 (*c*) 5·8(*h*) 2·4(*d*)			

(*a*) For 1-inch traversing. (*b*) For 64-inch traversing and computation. (*c*) For 1-inch (1½-inch fair-mapping). (*d*) For ½-inch. (*e*) For 4-inch. (*f*) For 3-inch. (*g*) For 2-inch. (*h*) For 64-inch traversing and computation. (*m*) For 24-inch.

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TABLE III.—*Concluded.*

COST-RATES OF SURVEY 1920-21.—*Concluded.*

Circle.	Party.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.																	COST-RATES, RUPEES.				Total plane-tabling out-turns on all scales, square miles.	Total cost of party. Rs.	REMARKS.
			¼-, ⅓-, & ½-inch	⅓- & ½-inch	½-inch	1-inch				1½-inch	2-inch		4-inch		8-inch	16-inch		64-inch	50-feet	Triangulation per square mile.	TRAVERSING PER LINEAR MILE.		Fair-mapping, per square mile.			
			Revision survey.	Original survey.	Original survey.	Original survey.	Re-survey.	Revision survey.	Supplementary survey.	Revision survey.	Original survey.	Supplementary survey.	Original survey.	Revision survey.	Military survey.	Original survey.	Revision survey.	Original survey.	Correction of plans.		Topographical.	Forest boundary.				
S	No 7	Madras ...	...	...	...	13·7	...	1·7	8·7	...	61·1	27·9	...	...	...	..	...	...	...	...	..	...	6·7	5,243	1,32,932	
	No. 8	Madras ...	...	...	...	47·8	...	...	22·2	...	57·5‡	...	...	...	...	...	...	...	...	...	...	...	12·5	5,161	1,89,547	‡ Includes Cost-rates for 55·20 square miles of 2-inch supplementary survey.
S	No. 20	Bangalore Civil and Military Station, Bangalore Bāzārs, Cannanore, Velichi, West Hill, Wellington and military land, Poonamallee, St. Thomas's Mount and bāzār and Deolāli. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	1·1(*j*)	1·8(*j*)	7·0(*j*)	28·3 (*j*)	205·9	76·0	...	0·6(*n*) (*j*) 15 1(*p*) (*j*) 39·2(*q*) (*j*)	15,467(*k*)	83,573	§ 4rd plane-tablers were pupils under instruction. ¶ All plane-tablers were pupils under instruction.
E	No. 9	Bengal and Bihār and Orissa. ...	...	...	...	39·4§	...	...	53·2¶	21·5	...	...	...	...	...	...	...	...	...	...	14·8	...	11·7	3,000	1,87,210	
E	No 10	Upper Burma ..	...	...	33·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16·2	...	...	13·2(*c*) 5·8(*d*)	3,843	2,32,417	An area of 183 square miles of rough reconnaissance has not been taken into account in these figures.
E	No. 11	Upper and Lower Burma ...	...	...	...	98·8	...	...	...	...	...	...	...	...	...	...	...	...	...	15·6(*c*) 6·7(*g*)	...	77·9	15·4(*c*) 1·1(*d*)	1,494	2,57,949	Includes cost of Maymyo Drawing Office.
E	No. 12	Assam ...	...	...	25·6	...	...	...	...	...	147·7	...	...	...	...	...	...	...	...	11·7	76·4	23·3	5·4(*d*) 31·9(*g*)	2,766	1,64,089	
E	No. 21 (Burma Forest)	Burma ...	...	...	...	...	...	...	...	...	191·7	...	532·7	...	...	...	...	...	...	30·8	...	94·0	75·0(*e*) 47·0(*g*)	172	1,39,533	

(*c*) For 1-inch (1½-inch fair mapping). (*d*) For ½-inch. (*e*) For 4-inch. (*g*) For 2-inch. (*j*) Per acre. (*k*) Acres. (*n*) For 16-inch. (*p*) For 64-inch. (*q*) For 50-feet.

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PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

TRIGONOMETRICAL SURVEY.

SUMMARY.

1. *General.*—The geodetic operations of four parties (page 45) have been in abeyance since the outbreak of war. This break, of over seven years, in the continuity of the personal tradition so valuable in this kind of expert work, is one of the most serious anxieties of the Trigonometrical Survey. Owing to shortage of staff, it has not yet been possible to do much to re-establish this tradition; but it is hoped that there may soon be opportunities of training young officers as geodetic observers; and designs for the preparation of a more complete set of observers' handbooks are also in hand. It is also being considered in what respects the organization of the whole work may be improved during the process of re-establishment.

2. *Training.*—During the year eleven Class I officers were posted to the office, for preliminary survey training, on first joining the department. This demand has had to be largely met by officers occupied with current duties, and it has not always been possible, owing to this circumstance, to give as satisfactory a course of instruction as could be wished.

3. *Office buildings and library.*—All branches of the work are suffering more or less severely from the want of suitable and adequate accommodation. The sanction for new buildings, accorded by Government some years ago, was cancelled owing to the war, and financial stringency is still blocking the way to efficient work in several directions.

The new librarian, Miss Keating, who has a good knowledge of foreign languages, has done much for the library, but the work is becoming hampered by lack of space.

4. *Experiment and Research.*—The first attempt at the determination of an Indian longitude by means of the *Paris wireless* "scientific" time-signals (page 102), opens up very interesting possibilities. This method is incomparably cheaper and more convenient than the older electro-telegraphic methods. It was gratifying to find that the results were closely accordant with the latest telegraphic determination.

We are in communication with experts at Home in regard to the most suitable equipment for the determination of wireless longitudes, with a view to the early development of further work on these lines; the method may lead to great economies in certain kinds of geographical survey, apart from its geodetic value.

It is hoped that Dr. de Graaff Hunter's original investigations in connection with *atmospheric refraction* (page 102), may ultimately lead to greater accuracy in the determination of heights. An apparatus for determining air temperatures at various heights up to 150 feet above the ground,—most important in this study,—has not yet been brought into use, owing to lack of personnel. It was ordered in 1913 but did not arrive till 1920.

Dr. Hunter has also just devised an interesting method for the expeditious adjustment of triangulation networks (page 103).

5. *Computing Office.*—The report on page 101 is itself a summary. The volume and variety of the work turned out by this office during the past 100 years can best be judged from the list of *Publications of the Survey of India* given in the Appendix to this Volume.

The charge at present includes several miscellaneous items, such as *type printing, book-binding, workshops, stores,* and *observatories,* and these are a great tax on the time of the Mathematical Adviser.

6. *Observatories.*—So far as weather permits, *time* is determined by star transits weekly. The observatory is still in need of "impersonal micrometers" but it is hoped that this want may be shortly repaired. *Meteorological and seismological* records and *solar photographs* are taken daily.

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7. *The Magnetic Survey.*—Observations were continued as usual at the magnetic observatories, and at repeat stations distributed over India (page 77), for the better determination of the annual changes in the magnetic elements.

A voluminous record of the work and results of the Magnetic Survey, during the 20 years since its commencement, is under preparation and is now approaching completion. The constants of all instruments have recently been re-determined, in order to strengthen the data for the computation of the results contained in this report. The recomputation of results in the light of the new constants has involved heavy labour (page 78).

The great magnetic storm in May 1921, which broke all previous records, and interrupted the working of Indian telegraphs, is described on page 78.

The serious condition of the Dehra Dūn observatory (page 79) as a result of the heavy monsoon, is a matter of grave anxiety, since this is the principal base station of the whole magnetic survey. Necessary action is under consideration.

8. *Levelling.*—Of the total out-turn of over 2,000 miles, the great bulk was carried out on behalf of various irrigation and engineering projects.

A result of some interest was obtained by a comparison of the new levelling across the Hardinge bridge, at Sāra Ghāt near Dāmukdia, with the results of the special experiments carried out, twenty years ago, to determine the best means of carrying levels across such broad expanses of water as the Ganges presents at this point (page 60).

Major Mason, in charge of this work, has also done a great deal of useful work throughout the year, on *Triangulation Pamphlets*, with a view to increasing their usefulness to explorers, and the public in general.

The Maintenance and Preservation of G. T. Stations was included with this charge during the year.

9. *Tidal Operations* have proceeded as usual, except for the recent change of policy in bringing out the *tide-predicting machine* from England, with a view to doing the whole work of tide-prediction, as well as the printing of tide-tables, in India in future, instead of in England.

This innovation will necessitate a slight increase of staff, both for prediction and printing. The predicting machine has arrived badly damaged and with a most inadequate supply of 200-foot rolls of paper. Delays on this account, at the outset, are giving rise to some anxiety, as the tide-tables for 1923 ought to be ready well beforehand, and the work of predicting cannot be commenced much before January 1922. Tide-tables are required for over 40 ports, between Suez to the Malay Peninsula.

10. *Himālayan Exploration* has always been co-ordinated in this office. During the year, two officers of the Survey of India accompanied the Mount Everest Expedition. Their report is given on page 109. The opportunity has been taken to experiment with two methods of photo-survey, including the stereoscopic. It is hoped that from some of the Everest stereo-photos so taken, maps will be plotted in Paris by the Orel auto-plotter.

A note by Major Mason on previous high climbs in the Himālayas will be found on page 107.

11. *Administrative control* of the Trigonometrical Survey was held by Major R. H. Thomas, D.S.O., R.E. up to the 16th November 1920, by Lieut.-Colonel H. L. Crosthwait, C.I.E., R.E. to the 13th March, and by Lieut.-Colonel H. McC. Cowie, R. E. to the end of the survey year, 30th September.

Colonel Sir Gerald Lenox-Conyngham, Kt., R.E., F.R.S. who recently retired after more than 30 years service in the Trigonometrical Survey, has just accepted the newly formed præ-lectorship in geodesy at Trinity College, Cambridge, where he has been elected to a Fellowship. We all hope this may prolong our personal touch with him, and be of assistance to us in keeping in touch with geodetic research, which at present engages much expert attention in Europe and America.

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No. 13 PARTY—ASTRONOMICAL, No. 14 PARTY—PENDULUM, No. 15 PARTY—TRIANGULATION AND No. 19 PARTY—BASE LINE OPERATIONS.

No field operations were carried out by these four parties, the personnel being employed at the Head-quarters offices of the Trigonometrical Survey, or on special duty.

TIDAL OPERATIONS.

By HANUMAN PRASAD.

During the year under report, the registration of tide curves by means of automatic tide-gauges was continued at the following ports:—

Aden, Karāchi, Bombay (Apollo Bandar), Bombay (Prince's Dock), Madras, Kidderpore, Rangoon, Moulmein and Port Blair.

These operations continued to be conducted under the direction of this department, the immediate control of the tidal observatories being entrusted as hitherto to the Port officers concerned.

PERSONNEL OF No. 16 PARTY.

Class I Officer.

Mr. O. C. Ollenbach in charge up to 12th May 1921.

Class II Officers.

Mr. Hanumān Prasad in charge from 13th May 1921.
Khan Sahib Syed Zille Hasnain up to 23rd May 1921.
Mr. D. H. Luxa.

Lower Subordinate Service.

20 Computers, etc.

In addition, comparisons between the predicted and actual times and heights of high and low-water for the year 1920 were carried out for the following ports:— Bhaunagar, Chittagong and Akyab. The actual times and heights of high and low-water of these ports were supplied monthly by the Port officers concerned. These readings were taken on a tide-pole, during day-light only, throughout the year. The object with which these comparisons were made, was to enquire whether the predictions still maintained a sufficient degree of accuracy, as these predictions were based on the observations of self-registering tide-gauges which had been discontinued many years ago.

TIDAL OBSERVATIONS AT BASRAH.

Readings of the height of the water against an ordinary wooden tide-pole were continued at Basrah. These readings were taken hourly throughout the day and night for the whole year. Copies of these readings were supplied to this department, weekly, by the Director, Inland Water Transport, Mesopotamia. The readings for the year commencing 1st January 1920, were reduced by harmonic analysis, and the constants thus deduced used in the computation of data for the Basrah tide-tables for 1922. These data were forwarded on the 6th January 1921, to the Director, National Physical Laboratory, Teddington, for use in the preparation of the tide-tables. The tide-tables for Basrah for 1922 were received on the 26th and 29th September 1921, and were despatched to the officials requiring them.

LIST OF TIDAL STATIONS.

The following is a complete list of the ports at which tidal registration has been carried out since the commencement of tidal operations in 1874 up to the present date. The stations at which automatic tide-gauges are still working are shown in italics, the others are minor stations, at which observations on self-registering tide-gauges were considered necessary for a few years only, and which were closed many years ago.

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List of Tidal Stations.

Serial No.	Stations	Automatic or Personal observations	Date of commencement of observations	Date of closing of observations	Number of years of observations		Remarks
1	Suez	Automatic	1897	1903	7		
2	Perim	,,	1898	1902	5		
3	*Aden*	,,	1879	Still Working	42		
4	Maskat	,,	1893	1898	5		
5	Būshire	,,	1892	1901	8		
6	*Karāchi*	,,	1868 Restarted 1881	1880 Still Working	*13 40	53	*Small tide-gauge working
7	Hanstal	,,	1874	1875	1		Tide-tables not published. Year 1904-05 is excluded.
8	Navānar	,,	1874	1875	1		
9	Okha Point ...	,,	1874 Restarted 1904	1875 1906	1 1	2	
10	Porbandar ...	Personal	1893	1894	2		
10A	Porbandar ...	Automatic	1898	1902	2		Years 1898, 1899 & 1902 are excluded.
11	Port Albert Victor (Kāthiāwār).	Personal	1881	1882	1		
11A	Port Albert Victor (Kāthiāwār).	Automatic	1900	1903	4		
12	Bhaunagar ...	,,	1889	1894	5		
13	*Bombay (Apollo Bandar)*	,,	1878	Still Working	43		
14	*Bombay (Prince's Dock)*	,,	1888	,,	33		
15	Marmagao (Goa)	,,	1884	1889	5		
16	Kārwār	,,	1878	1883	5		
17	Beypore	,,	1878	1884	6		
18	Cochin	,,	1886	1892	6		
19	Tuticorin	,,	1888	1893	5		
20	Minicoy	,,	1891	1896	5		
21	Galle	,,	1884	1890	6		
22	Colombo	,,	1884	1890	6		
23	Trincomalee ...	,,	1890	1896	6		
24	Pāmban Pass ...	,,	1878	1882	4		
25	Negapatam ...	,,	1881	1888	5		Years 1883 to 1885 are excluded.
26	*Madras*	,,	1880 Restarted 1895	1890 Still Working	10 26	36	
27	Cocanāda	,,	1886	1891	5		
28	Vizagapatam ...	,,	1879	1885	6		
29	False Point ...	,,	1881	1885	4		
30	Dublat (Sāgar Island)	,,	1881	1886	5		
31	Diamond Harbour	,,	1881	1886	5		
32	*Kidderpore* ...	,,	1881	Still Working	40		
33	Chittagong ...	,,	1886	1891	5		
34	Akyab	,,	1887	1892	5		
35	Diamond Island	,,	1895	1899	5		
36	Bassein (Burma)	,,	1902	1903	2		
37	Elephant Point	,,	1880 Restarted 1884	1881 1888	5		Year 1880-81 is excluded.
38	*Rangoon*	,,	1880	Still Working	41		
39	Amherst	,,	1880	1886	6		
40	*Moulmein* ...	,,	1880 Restarted 1909	1886 Still Working	6 12	18	
41	Mergui	,,	1889	1894	5		
42	*Port Blair* ...	,,	1880	Still Working	41		
43	*Basrah*	Personal	1916	,,	5		Observations taken on a tide-pole.

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Inspection of the Tidal Observatory.

Mr. O. C. Ollenbach inspected the tidal observatories at Kidderpore, Rangoon and Moulmein.

The tidal observatory at Aden was inspected by Khan Sahib Syed Zille Hasnain.

Mr. D. H. Luxa inspected the tidal observatories at Karāchi, Bombay (Apollo Bandar), Bombay (Prince's Dock), Madras and Port Blair.

Each observatory was carefully inspected, due regard being paid to the following points:—

(a) Working zero of tide-gauge checked and compared with the true zero.

(b) Stability of tide-gauge tested by check-levelling between its bed-plate and the bench-mark of reference.

(c) Zero of graduated staff and tide-gauge tested with reference to one another.

(d) Instruments thoroughly cleaned and overhauled and left in good working order.

(e) Tide-gauge and working zero finally adjusted after cleaning the whole apparatus.

(f) The observatory well and inlet hole examined and cleaned, so as to ensure free communication being maintained between the sea and the well.

(g) General examination of the observatory cabin in order to have any necessary repairs carried out by the Port Engineer or other official concerned.

Remarks regarding the Working of each Tidal Observatory.

Aden.—This was inspected in February 1921 and was found to have worked more or less satisfactorily since the previous inspection in January 1920, except for a few minor interruptions in the registrations of the tidal curves, owing to the stopping of the driving clock. This clock and the spare one in the observatory were both thoroughly overhauled and cleaned and the old clock replaced by the spare one, the two clocks being interchangeable.

The Port Overseer who was entrusted with the caretaking of the observatory, appears to have exercised his supervision with zeal and intelligence. His remarks in the observatory reports bear testimony to the care and attention with which he has watched the working of the tide-gauge.

Karāchi.—Since the last inspection of this observatory, there has been a vast improvement as regards the number of interruptions in the registration of the tidal curves, which used previously to be of frequent occurrence. During the past year only three interruptions occurred: these happened on the 25th October and on the 23rd and 24th November 1920, varying in duration from $3\frac{3}{4}$ to 6 and 5 hours respectively. With the exception of these three breaks, the registration of the tide curves has been almost continuous. This improvement is due to the observatory clerk having kept a careful watch to see that the inlet hole between the cylinder of the tide-gauge and the sea was free from obstructions of any kind; in this he was greatly helped by having the services of a diver placed at his disposal.

Bombay (Apollo Bandar).—There have been, since the previous inspection, no breaks in the registration of the tide curves at this observatory. The tide-gauge well was cleaned twice during the past year viz., in May and November 1920.

Bombay (Prince's Dock).—Since the last inspection of this observatory there have been nine interruptions in the registrations of the tide curves, varying in duration from 5 to a little over 24 hours: these breaks in registration were generally due to the driving clock of the gauge having stopped or to the pencil wire having snapped. On one occasion the point of the registering pencil entered a hole in the diagram paper, and slit it along a line parallel to the zero line on the diagram. The well of this observatory was cleaned out on the 27th and 28th November 1920.

Madras.—There have been no breaks in the registration of the tide curves at this observatory. This satisfactory result is due to the observatory clerk having carried out his duties with great care and attention.

Kidderpore.—The tide-gauge at this observatory has worked well. There was only one break in the registration of the tide curve during the past year, and this occurred on the 16th October 1920, owing to the stoppage of the driving clock, which was restarted after a break of nearly 10 hours. The cylinder was examined and a fair amount of silt was removed, the cylinder not having been cleaned for some time. Arrangements were made to have the cylinder cleaned out once in every three months.

Rangoon.—This observatory was found to be in good order. Four interruptions in the registration of the tide curves occurred during the past year, three of these were due to

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the stoppage of the driving clock and one to the pencil failing to register, owing to the snapping of the cord which had become worn out.

Moulmein.—The tide-gauge at this observatory has worked well during the past year. Only one interruption occurred since it was last inspected, due to the band having slipped off the stud wheel of the tide-gauge on the night of the 24th January 1921. This was readjusted the next morning.

Port Blair.—This observatory has continued to work very well, not a single break in the registration of the tide curves having occurred since it was last inspected. This is due to the great interest taken by the Engineer and Harbour Master of the port, and to the care and attention paid to the observatory by the clerk in charge of it and his assistant.

Computations and Reductions of Observations.

All the computations of the year's work have been completed and there are no arrears. The tidal observations at the nine working stations for the year 1920 have been reduced by harmonic analysis. In addition, the hourly readings for the year 1920 taken on a tide-pole at Basrah, and supplied weekly to this department by the Director, Inland Water Transport, Mesopotamia, have been similarly treated. The tidal constants deduced from these reductions, are shown in the accompanying tables. These give the amplitudes (R) and the epochs (ζ) at Basrah and the nine working stations. The values of (H) and (K) are also given, and these are connected with (R) and (ζ), through the various astronomical quantities involved in the positions of the sun and moon, in such a way, that if the tidal observations were consistent from year to year, (H) and (K) would result in being the same for each year's reductions.

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1920

Tide Symbol	ADEN $A_0=5\cdot871$				KARĀCHI $A_0=7\cdot377$				BOMBAY (Apollo Bandar) $A_0=10\cdot277$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·088	169·43	0·088	169·43	0·094	177·56	0·094	177·56	0·073	181·96	0·073	181·96
S_2	0·663	246·70	0·663	246·70	0·974	322·85	0·974	322·85	1·542	6·19	1·542	6·19
S_4	0·007	297·35	0·007	297·35	0·010	358·25	0·010	358·25	0·020	261·71	0·020	261·71
S_6	0·005	225·74	0·005	225·74	0·009	291·22	0·009	291·22	0·006	170·71	0·006	170·71
S_8	0·001	325·01	0·001	325·01	0·001	54·46	0·001	54·46	0·003	143·13	0·003	143·13
M_1	0·086	159·66	0·096	53·86	0·079	171·13	0·088	66·06	0·093	170·72	0·104	65·85
M_2	1·611	112·67	1·567	228·83	2·693	175·84	2·621	293·49	4·135	214·77	4·023	332·81
M_3	0·016	234·42	0·015	228·65	0·046	341·93	0·044	338·39	0·073	36·68	0·070	33·74
M_4	0·005	125·84	0·004	358·15	0·016	115·71	0·015	350·99	0·125	67·91	0·119	304·00
M_6	0·007	35·31	0·006	23·77	0·048	196·59	0·044	189·51	0·025	38·97	0·023	33·10
M_8	0·004	321·95	0·003	66·57	0·001	348·69	0·001	99·26	0·013	253·25	0·012	5·42
O_1	0·583	121·95	0·669	38·12	0·595	130·48	0·682	48·20	0·579	132·45	0·665	50·59
K_1	1·199	198·43	1·302	34·90	1·229	209·29	1·334	45·70	1·278	209·51	1·387	45·91
K_2	0·142	29·50	0·174	241·61	0·193	102·03	0·238	314·03	0·293	149·49	0·360	1·45
P_1	0·406	220·73	0·406	31·01	0·400	231·75	0·400	42·08	0·391	231·77	0·391	42·12
J_1	0·108	242·38	0·121	56·61	0·104	255·51	0·117	68·88	0·100	256·38	0·113	69·52
Q_1	0·134	89·91	0·154	31·84	0·140	98·54	0·160	42·81	0·135	100·64	0·155	45·54
L_2	0·045	295·99	0·038	208·95	0·068	13·87	0·056	287·51	0·092	51·06	0·077	324·89
N_2	0·440	80·18	0·428	222·09	0·617	132·94	0·600	277·14	0·998	170·64	0·971	315·45
ν_2	0·012	98·60	0·012	303·72	0·018	75·50	0·018	282·79	0·006	174·09	0·006	21·97
μ_2	0·076	325·55	0·072	197·86	0·074	36·51	0·070	271·79	0·241	71·64	0·228	307·73
T_2	0·028	188·13	0·028	189·97	0·032	274·18	0·032	276·08	0·039	335·61	0·039	337·52
$(MS)_4$	0·012	57·17	0·011	173·33	0·038	188·67	0·037	306·32	0·079	248·31	0·077	6·35
$(2SM)_2$	0·026	212·95	0·025	96·80	0·021	198·52	0·020	80·88	0·040	250·79	0·039	132·75
$2N_2$	0·111	17·94	0·108	185·61	0·122	60·47	0·118	231·22	0·178	93·00	0·173	264·58
$(M2N)_4$	0·007	326·55	0·007	224·61	0·024	104·65	0·022	6·49	0·028	347·38	0·026	250·23
$(M_2K_1)_3$	0·041	28·35	0·044	340·97	0·054	80·73	0·057	34·78	0·045	154·60	0·048	109·03
$(2M_2K_1)_3$	0·006	275·53	0·007	311·37	0·025	281·78	0·025	320·65	0·060	5·24	0·061	44·93
Long Period		°		°		°		°		°		°
Mm	0·041	22·01	0·037	356·26	0·065	356·51	0·059	329·96	0·094	347·63	0·086	320·87
Mf	0·034	250·80	0·046	354·61	0·033	225·36	0·045	327·57	0·046	240·27	0·062	342·05
MSf	0·001	326·68	0·001	210·53	0·021	343·92	0·020	226·28	0·040	339·98	0·039	221·94
Sa	0·388	77·22	0·388	356·95	0·229	156·81	0·229	76·48	0·154	83·03	0·154	2·67
Ssa	0·096	288·44	0·096	127·89	0·038	328·94	0·038	168·27	0·107	2·55	0·107	201·85

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1920

Tide Symbol	BOMBAY (Prince's Dock) $A_0 = 8 \cdot 271$				MADRAS $A_0 = 2 \cdot 317$				KIDDERPORE $A_0 = 10 \cdot 169$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·093	182·46	0·093	182·46	0·033	81·55	0·033	81·55	0·082	196·69	0·082	196·69
S_2	1·612	5·09	1·612	5·09	0·451	268·55	0·451	268·55	1·527	97·80	1·527	97·80
S_4	0·018	233·20	0·018	233·20	0·002	190·31	0·002	190·31	0·089	108·27	0·089	108·27
S_6	0·005	191·73	0·005	191·73	0·002	30·96	0·002	30·96	0·007	357·65	0·007	357·65
S_8	0·002	18·44	0·002	18·44	0·002	296·57	0·002	296·57	0·006	269·03	0·006	269·03
M_1	0·094	170·41	0·105	65·53	0·024	48·47	0·026	303·84	0·038	71·42	0·043	327·06
M_2	4·239	213·30	4·125	331·34	1·135	121·01	1·104	239·56	3·952	296·74	3·846	55·83
M_3	0·082	38·48	0·079	35·55	0·005	358·81	0·005	356·63	0·052	330·65	0·050	329·28
M_4	0·126	97·27	0·119	333·36	0·006	292·54	0·006	169·64	0·792	153·72	0·750	31·90
M_6	0·005	108·44	0·004	102·57	0·005	106·11	0·005	101·75	0·182	318·67	0·167	315·94
M_8	0·010	291·67	0·009	43·84	0·003	121·43	0·002	235·61	0·083	160·37	0·074	276·73
O_1	0·583	131·15	0·670	49·29	0·083	44·61	0·096	323·27	0·176	98·64	0·202	17·86
K_1	1·290	208·46	1·401	44·86	0·271	139·12	0·294	335·49	0·392	215·81	0·426	52·16
K_2	0·309	144·85	0·381	356·81	0·085	53·77	0·105	265·69	0·325	240·54	0·399	92·41
P_1	0·393	231·23	0·393	41·58	0·091	166·01	0·091	336·38	0·158	234·03	0·158	44·42
J_1	0·107	259·66	0·120	72·80	0·021	171·79	0·024	344·64	0·028	236·54	0·032	49·07
Q_1	0·138	101·20	0·159	46·11	0·009	78·44	0·010	24·14	0·021	59·37	0·024	5·92
L_2	0·087	33·05	0·073	306·88	0·045	334·59	0·037	248·65	0·220	140·35	0·184	54·67
N_2	1·012	170·48	0·985	315·29	0·238	85·20	0·232	230·78	0·645	258·65	0·628	45·07
ν_2	0·018	65·88	0·018	273·76	0·015	41·51	0·015	250·12	0·135	161·18	0·131	10·60
μ_2	0·225	75·89	0·213	311·98	0·038	307·33	0·036	184·43	0·315	295·61	0·298	173·79
T_2	0·060	336·92	0·060	338·83	0·017	203·55	0·017	205·49	0·067	180·17	0·067	182·14
$(MS)_4$	0·113	279·33	0·110	37·38	0·004	109·29	0·004	227·84	0·692	312·63	0·673	71·72
$(2SM)_2$	0·047	224·65	0·046	106·61	0·014	336·52	0·013	217·97	0·073	117·70	0·071	358·61
$2N_2$	0·178	89·41	0·173	260·99	0·052	41·05	0·051	213·67	0·240	192·93	0·233	6·68
$(M_2N)_4$	0·016	52·83	0·015	315·68	0·004	165·96	0·004	70·09	0·276	113·42	0·261	18·95
$(M_2K_1)_3$	0·068	158·54	0·072	112·97	0·016	33·79	0·017	348·71	0·094	94·74	0·100	50·18
$(2M_2K_1)_3$	0·069	21·58	0·071	61·28	0·002	287·35	0·002	328·08	0·041	257·08	0·042	298·91
Long Period		°		°		°		°		°		°
Mm	0·087	339·70	0·079	312·93	0·076	355·69	0·069	328·65	0·278	66·00	0·254	38·67
Mf	0·056	227·45	0·076	329·23	0·024	229·01	0·032	330·24	0·173	266·91	0·234	7·55
MSf	0·010	310·74	0·010	192·69	0·022	35·91	0·021	277·37	0·825	162·70	0·803	43·61
Sa	0·196	72·04	0·196	351·69	0·307	291·27	0·307	210·90	1·796	226·69	1·796	146·30
Ssa	0·151	2·08	0·151	201·38	0·191	281·79	0·191	121·04	0·721	123·14	0·721	322·35

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1920

Tide Symbol	RANGOON $A_0 = 10 \cdot 309$				MOULMEIN $A_0 = 8 \cdot 636$				PORT BLAIR $A_0 = 4 \cdot 887$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·123	132·93	0·123	132·93	0·101	143·20	0·101	143·20	0·021	88·90	0·021	88·90
S_2	2·048	167·41	2·048	167·41	1·436	145·25	1·436	145·25	0·943	313·58	0·943	313·58
S_4	0·086	265·60	0·086	265·60	0·061	219·30	0·061	219·30	0·003	171·63	0·003	171·63
S_6	0·010	32·38	0·010	32·38	0·010	211·88	0·010	211·88	0·001	285·26	0·001	285·26
S_8	0·005	84·92	0·005	84·92	0·002	106·39	0·002	106·39	0·002	49·09	0·002	49·09
M_1	0·027	201·41	0·030	97·31	0·016	176·02	0·018	71·97	0·036	50·24	0·040	306·02
M_2	5·976	9·38	5·815	129·00	4·184	352·00	4·071	111·72	2·050	160·67	1·995	280·05
M_3	0·031	41·75	0·030	41·18	0·026	59·08	0·025	58·65	0·006	7·39	0·005	6·47
M_4	0·510	286·88	0·483	166·12	0·986	286·30	0·933	165·74	0·016	216·65	0·015	95·43
M_6	0·256	84·21	0·236	83·07	0·075	187·16	0·069	186·31	0·002	66·04	0·002	64·20
M_8	0·086	338·44	0·077	96·92	0·057	348·93	0·051	107·80	0·003	311·19	0·002	68·74
O_1	0·273	110·12	0·314	29·90	0·249	128·52	0·286	48·40	0·133	21·26	0·153	300·80
K_1	0·635	199·87	0·690	36·20	0·430	204·30	0·467	40·63	0·380	130·17	0·412	326·51
K_2	0·421	315·26	0·518	167·09	0·265	297·14	0·326	148·97	0·189	96·93	0·232	308·78
P_1	0·163	241·73	0·163	52·15	0·134	241·67	0·134	52·09	0·134	151·48	0·134	321·89
J_1	0·057	293·50	0·064	105·74	0·037	285·90	0·041	98·08	0·026	176·49	0·030	348·86
Q_1	0·028	86·97	0·033	34·35	0·033	97·94	0·038	45·48	0·010	345·96	0·011	292·99
L_2	0·411	225·96	0·343	140·52	0·276	206·54	0·231	121·14	0·088	355·84	0·073	270·30
N_2	0·964	326·91	0·938	114·14	0·698	312·39	0·679	99·78	0·385	126·81	0·375	273·69
ν_2	0·172	249·94	0·167	100·13	0·135	231·80	0·131	82·13	0·008	48·95	0·008	258·79
μ_2	0·537	45·22	0·509	284·46	0·363	36·00	0·344	275·44	0·088	56·53	0·083	295·31
T_2	0·109	123·57	0·110	125·56	0·085	102·04	0·085	104·03	0·046	267·36	0·046	269·33
$(MS)_4$	0·477	88·45	0·464	208·07	0·747	85·41	0·726	205·12	0·013	56·18	0·012	175·57
$(2SM)_2$	0·155	163·93	0·151	44·31	0·118	161·63	0·115	41·91	0·021	251·21	0·020	131·82
$2N_2$	0·351	275·19	0·342	90·04	0·241	250·35	0·235	65·40	0·073	54·68	0·071	229·05
$(M_2N)_4$	0·196	252·45	0·185	159·30	0·362	244·41	0·343	151·52	0·005	124·99	0·005	31·26
$(M_2K_1)_3$	0·086	135·90	0·093	91·85	0·150	142·96	0·159	99·00	0·022	53·34	0·023	9·07
$(2M_2K_1)_3$	0·117	6·92	0·120	49·83	0·114	16·69	0·117	59·80	0·008	177·10	0·008	219·54
Long Period		°		°		°		°		°		°
Mm	0·196	48·57	0·179	20·96	0·359	44·70	0·328	17·03	0·035	5·93	0·032	338·44
Mf	0·090	323·57	0·122	63·64	0·252	316·13	0·341	56·09	0·028	259·70	0·038	0·02
MSf	0·503	162·67	0·489	43·05	1·164	162·48	1·133	42·76	0·010	125·65	0·010	6·26
Sa	1·106	225·11	1·106	144·69	2·296	226·02	2·296	145·60	0·196	207·43	0·196	127·02
Ssa	0·119	122·24	0·119	321·41	0·691	96·43	0·691	295·59	0·109	343·34	0·109	182·53

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1920

Tide Symbol	BASRAH											
	$A_0 = 6 \cdot 540$				$A_0 =$				$A_0 =$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°								
S_1	0·166	196·67	0·166	196·67								
S_2												
S_4												
S_6												
S_8												
M_1												
M_2	1·325	349·44	1·289	105·78								
M_3												
M_4												
M_6												
M_8												
O_1	0·384	80·99	0·441	357·36								
K_1	0·697	194·68	0·757	31·14								
K_2												
P_1	0·189	192·57	0·189	2·85								
J_1	0·018	324·32	0·021	138·44								
Q_1	0·059	53·05	0·068	355·28								
L_2												
N_2												
ν_2												
μ_2												
T_2												
$(MS)_4$												
$(2SM)_2$												
$2N_2$												
$(M_2N)_4$												
$(M_2K_1)_3$	0·205	91·95	0·217	44·75								
$(2M_2K_1)_3$	0·198	329·46	0·204	5·70								
Long Period												
Mm												
Mf												
MSf												
Sa												
Ssa												

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Data forwarded to England.

The following data were prepared and supplied to the Director, National Physical Laboratory, Teddington, during the year under report :—

(*a*) Values of the tidal constants for the tide-tables for Basrah for the year 1922.

(*b*) Actual heights and times of high and low-water during 1919 at 12 stations. These include 9 stations at which regular observations by self-registering tide-gauges were carried out, and three stations at which the times and heights of high and low-water readings were taken during day-light on watches and tide-poles respectively.

(*c*) Comparisons of the observed against predicted values for 1919, the errors being tabulated so as to be of use in improving future predictions, if possible. In addition, the values of the tidal constants for the 40 Indian ports for the tide-tables for 1924, were also derived in readiness for use with the tide-predicting machine, which was then being sent out to India.

Errors in Predictions.

The predicted times and heights for high and low-waters for the year 1920, have been compared against the actual values as observed at the nine stations now working, and at the three other stations where the use of self-registering tide-gauges had been discontinued, but at which the times and heights of high and low-waters during day-light were noted by means of a watch and a tide-pole. The errors of the predictions as compared with the actual times and heights of high and low-water thus determined, are tabulated in the 6 tables appended hereto.

No. 1.

Percentages and amounts of the errors in the predicted times of high-water at the various tidal stations for the year 1920.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent	Per cent	Per cent	Per cent	Per cent
Aden ...	Auto.	695	21	40	14	16	9
Karāchi ...	,,	705	34	43	11	8	4
Bhaunagar ...	T.P.	365	67	33	0	0	0
Bombay (Apollo Bandar)	Auto.	707	40	48	7	3	2
Bombay (Prince's Dock)	,,	707	43	43	6	6	2
Madras ...	,,	706	49	42	6	3	0
Kidderpore ...	,,	706	30	42	13	12	3
Chittagong ...	T.P.	366	11	48	14	19	8
Akyab ..	,,	366	99	1	0	0	0
Rangoon ...	Auto.	707	33	47	11	8	1
Moulmein ...	,,	707	29	48	11	10	2
Port Blair ...	,,	707	50	40	6	3	1

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No. 2.

Percentages and amounts of the errors in the predicted times of low-water at the various tidal stations for the year 1920.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent	Per cent	Per cent	Per cent	Per cent
Aden ...	Auto.	694	28	40	13	12	7
Karāchi ...	,,	707	34	38	10	11	7
Bhaunagar ...	T. P.	365	67	33	0	0	0
Bombay (Apollo Bandar)	Auto.	708	32	49	11	6	2
Bombay (Prince's Dock)	,,	707	35	46	8	8	3
Madras ...	,,	707	49	44	5	2	0
Kidderpore ...	,,	707	34	41	10	10	5
Chittagong ...	T. P.	366	8	47	16	20	9
Akyab ...	,,	366	100	0	0	0	0
Rangoon ...	Auto.	707	26	44	12	14	4
Moulmein ...	,,	707	18	35	12	21	14
Port Blair ...	,,	707	46	44	5	4	1

No. 3.

Percentages and amounts of the errors in the predicted heights of high-water at the various tidal stations for the year 1920.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent	Per cent	Per cent	Per cent
Aden ...	Auto.	695	6·7	98	2	0	0
Karāchi ...	,,	705	9 3	56	32	11	1
Bhaunagar ...	T.P.	365	31·4	65	33	2	0
Bombay (Apollo Bandar)	Auto.	707	13·9	63	29	7	1
Bombay (Prince's Dock)	,,	707	13 9	54	32	11	3
Madras ...	,,	706	3·5	88	12	0	0
Kidderpore ...	,,	706	11 7	31	22	17	30
Chittagong ...	T.P.	366	13 3	35	31	19	15
Akyab ...	,,	366	8·3	71	23	4	2
Rangoon ...	Auto.	707	16·4	47	29	17	7
Moulmein ...	,,	707	12·7	38	25	19	18
Port Blair ...	,,	707	6·6	98	2	0	0

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No. 4.

Percentages and amounts of the errors in the predicted heights of low-water at the various tidal stations for the year 1920.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent	Per cent	Per cent	Per cent
Aden ...	Auto.	694	6·7	97	3	0	0
Karāchi ...	,,	707	9·3	79	18	2	1
Bhaunagar ...	T.P.	365	31·4	61	36	3	0
Bombay (Apollo Bandar)	Auto.	708	13·9	70	25	3	2
Bombay (Prince's Dock)	,,	707	13·9	63	27	8	2
Madras ...	,,	707	3·5	89	11	0	0
Kidderpore ...	,,	707	11·7	36	22	12	30
Chittagong ..	T.P.	366	13·3	21	25	24	30
Akyab ...	,,	366	8·3	76	20	3	1
Rangoon ...	Auto.	707	16·4	35	27	18	20
Moulmein ...	,,	707	12·7	41	25	14	20
Port Blair ...	,,	707	6·6	98	2	0	0

No. 5.

Table of average errors in the predicted times and heights of high and low-water at the several tidal stations for the year 1920.

Stations.	Automatic or tide-pole observations.	Mean range at springs in feet.	Average Errors					
			of time in minutes.		of height in terms of the range.		of height in inches.	
Open Coast.			H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
Aden	Auto.	6·7	15	13	0·025	0·025	2	2
Karāchi	,,	9·3	11	12	0·045	0·027	5	3
Bhaunagar	T.P.	31·4	4	5	0·011	0·011	4	4
Bombay (Apollo Bandar)	Auto.	13·9	9	10	0·024	0·024	4	4
Bombay (Prince's Dock)	,,	13·9	9	10	0·030	0·024	5	4
Madras	,,	3·5	7	7	0·048	0·048	2	2
Akyab	T.P.	8·3	2	2	0·040	0·030	4	3
Port Blair	Auto.	6·6	7	8	0·025	0·025	2	2
General Mean	...	...	8	8	0·031	0·027	4	3
Riverain.								
Kidderpore	Auto.	11·7	11	11	0·071	0·071	10	10
Chittagong	T.P.	13·3	15	16	0·044	0·063	7	10
Rangoon	Auto.	16·4	10	12	0·030	0·041	6	8
Moulmein	,,	12·7	11	17	0·052	0·052	8	8
General Mean	...	...	12	14	0·049	0·057	8	9

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No. 6.

Summary for 1920.

Number of stations.	Predictions tested by	Percentage of Predictions, at high and low-water within					
		15 minutes of actuals.		8 inches of actuals.		one-tenth of mean range	
		High.	Low.	High.	Low.	High.	Low.
6 Open coast	S. R Tide-gauge	82	81	94	97	97	98
2 ,,	Tide-pole	100	100	96	97	98	99
3 Riverain	S. R. Tide-gauge	76	66	64	62	89	86
1 ,,	Tide-pole	59	55	66	46	94	84

Comparisons of the Predictions for the year 1920 with those for the previous year.

On comparing the tidal predictions for the nine working stations for the year 1920 with those for the year 1919, it was seen that the prediction of times for Aden had deteriorated, but had improved greatly for Madras and Kidderpore. The prediction of times at other stations, and of heights of all stations, except Kidderpore, were practically of the same standard of accuracy as those for the year 1919.

The greatest difference between the actual and predicted heights of low-water for 1920 at the riverain ports was as follows :—

Kidderpore ... 3 feet 1 inch on the 28th October 1920,

Rangoon ... 2 feet 5 inches on the 14th November 1920,

Moulmein ... 2 feet 7 inches on the 19th and 20th August 1920, the actual low-water being lower, in all three cases, than the predicted.

Tide-Tables.

The tide-tables for the Indian ports for the year 1921 were received from England on the 3rd and 17th December 1920, those for Basrah on the 21st December 1920. They were immediately distributed to the various Port authorities and other officials. The tide-tables for Basrah for 1922 were received on the 26th and 29th September 1921, and have been despatched to the authorities requiring them.

The tide-tables for the Indian ports for the year 1922 were received in November 1921 and duly distributed to the various Port officials.

The amount realised by the sale of tide-tables during the year ending 30th September 1921, was Rs. 2,855/12/0, exclusive of outstandings still unadjusted on the sale of tide-tables for the year 1921.

The Tide-Predicting Machine.

This machine has now been brought to India for the first time, particulars regarding it are given in the General Report for 1920-21.

Programme for season 1921-22.

During the coming field season, tide observation will be continued at the nine observatories working last year.

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LEVELLING.

By Brevet-Major K. Mason, M. C., R. E.

I. The party was increased from two double detachments to four double and 1 special detachments for the season.

Personnel of No. 17 Party.

Class I Officer.

Bt.-Major K. Mason, M. C., R. E., in charge.

Class II Officers.

Mr. O. N. Pushong.
„ R. B. Mathur, B. A.
„ K. S. Gopalachari, B. A.
„ N. N. Chuckerbutty, L. C. E.

Upper Subordinate Service.

Mr. K. K. Das, B. A.
„ S. C. Mukerjee.
„ P. B. Roy.
„ A. A. S. Matlub Ahmad.

Lower Subordinate Service.

10 Computers.
2 Recorders.
3 Clerks.

Office closed at Mussoorie on 6th October 1920, and opened at Dehra Dūn on the 11th. All detachments took the field between 19th and 23rd October, with the exception of the Lahore City detachment which was not formed till early in 1921. All returned to recess in Mussoorie by the end of May 1921, with the exception of No. 1 Detachment which was delayed by the early hot weather in Rājputāna.

II. Field Detachments were as follows:—

No. 1 Detachment. Mr. Chuckerbutty in charge; second leveller, Mr. Matlub Ahmad. The former had charge of 1 A, the latter of 1 B; the work being largely carried out on the "fore and back" system.

No. 2 Detachment. Mr. Pushong in charge; second leveller, computer Abdul Majid.

No. 3 Detachment. Mr. Mukerjee in charge; second leveller, Mr. P. B. Roy.

No. 4 Detachment. Mr. Mathur in charge 4 A; Mr. Gopalachari in charge 4 B.

Lahore City Detachment. Mr. K. K. Das in charge; three assistant levellers, who were specially enlisted and trained.

III. Programme. The programme was allotted to these detachments as follows; except where otherwise stated the lines are new.

No. 1 Detachment.

A. In Bengal and Bihār, for the Nadiā rivers scheme. From Tinpahār to Jiāganj. (Part of line 77 M).

B. In the United Provinces and Rājputāna. From Muttra to Mārwār Pāli. This forms line No. 107 of the new level net of high precision in India.

No. 2 Detachment.

C. In the United Provinces. Revision of the line from Bareilly to Pīlībhīt along the trunk road, originally levelled in 1867-68. (Line 64 A).

D. In the United Provinces, for the Sārdā Canal Project.

(i) From Pīlībhīt to Mailānī, by the railway line. (Line 64 D).

(ii) From Shāhjahānpur by road to Mailānī, thence by the railway to Kherī-Lakhīmpur, and by road thence to Sītāpur. (Line 64 E).

(iii) From Sītāpur *via* Baghauli railway station to Lucknow, with a branch to Mādhoganj. (Line 64 F).

(iv) From Lucknow *via* Rāe Barelī and Sultānpur to Fyzābād by road. (Line 68 A).

(v) From Sultānpur to Allahābād by road. (Line 67 A).

No. 3 Detachment.

E. In Bengal, for the Nadiā rivers scheme.

(i) From Chākdaha to Berhampore. (Part of line 77 L).

(ii) From Berhampore to Jayrāmpur. (Part of line 77 L).

(iii) From Berhampore to Jiāganj, with a branch line to Lālgolā. (Part of line 77 M).

F. In Bihār and Bengal, for the Nadiā rivers scheme. From Porādaha, *via* Nator to Rautāra; this line was undertaken to revise, by direct levelling over the Hardinge bridge, the crossing of the Ganges at Sāra. (Line 77 N).

G. In Bihār, for the Irrigation department.

From Darbhangā to Bagahā by the B. & N. W. Ry. (Line 71 A).

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No. 4 Detachment.

H. In the United Provinces, for the Sārdā Canal Project.

From Shāhjahānpur to Baghauli by road. (Line 64 G).

I. In Bombay and Baluchistān for the Sukkur Barrage Project.

From Jacobābād to Hyderābād, *via* Sehwān and Kotri. This forms part of line 101 of the new level net of high precision for India and takes the place of old line 53, levelled in 1858-60, on which all the bench-marks were reported destroyed.

Lahore City Detachment.

J. In the city and neighbourhood of Lahore, undertaken at the request of the local authorities for the City Sanitation scheme.

IV. Instruments, etc. In the case of the four regular detachments, binocular levels were used; staves were of the Survey Committee pattern. Weekly comparisons were made in the field against 10-foot standard tapes in order to determine as nearly as possible the variation in the length of the staves due to changes of humidity.

The Lahore city levellers used the small pattern Zeiss field level and collapsible staves.

V. Out-turn. Table I shows a detailed statement of the out-turn of the various detachments. It may be summarized as consisting of:—

(A) 85 miles of secondary levelling; the heights of 67 secondary bench-marks were determined.

(B) 349 miles of high precision levelling; the heights of 5 primary and 293 secondary bench-marks were determined.

(C & D) 549 miles of secondary levelling; the heights of 25 primary and 556 secondary bench-marks were determined.

(E, F & G) 621 miles of secondary levelling; the heights of 19 primary and 411 secondary bench-marks were determined.

(H) 59 miles of secondary levelling; the heights of one primary and 55 secondary bench-marks were connected.

(I) 336 miles of high precision levelling; the heights of 5 primary and 254 secondary bench-marks were connected.

The total out-turn is therefore 685 miles of high precision levelling and 1314 miles of secondary work, in addition to the Lahore city levelling, which may be classed as tertiary.

The heights of 55 primary, 1,636 secondary, and 259 tertiary (in Lahore) bench-marks were determined.

VI. River crossings. No special methods were employed for river crossings during the season, the Indus near Hyderābād, the Jalangī near Krishnagar, and the Ganges (Padmā) at Sāra being crossed by main bridges. A note as to the agreement of the new values of the last named with the values derived by old methods is included below in the discussion on results.

No. 3 Detachment crossed the Churnī at Rānāghāt, the Jalangī near Patkabāri, and several other broad *khāls* and *bils* by direct levelling.

VII. Probable accidental and systematic errors.

(i). The probable and mean accidental and systematic errors in feet per mile for the 'fore and back' lines were computed according to the formulæ

$$\eta_r^2 = \frac{1}{9}\left[\frac{\Sigma\Delta^2}{\Sigma L} - \frac{\Sigma r^2}{(\Sigma L)^2}\cdot\Sigma\frac{s^2}{L}\right]$$

$$\text{and } \sigma r^2 = \frac{1}{9\Sigma L}\cdot\Sigma\frac{s^2}{L}$$

(*vide* page 37, "Levelling of Precision", 1920) and are as tabulated below.

The maximum errors permissible in each class to admit of the work being classified as "Levelling of High Precision" are also shown.

Line	Probable accidental	Maximum permissible	Mean accidental	Maximum permissible	Probable systematic	Maximum permissible	Mean systematic	Maximum permissible
	foot.	*foot.*	*foot.*	*foot.*	*foot.*	*foot.*	*foot.*	*foot.*
(*B*) Muttra to Mārwār Pāli	±0·00373	±0·00416	±0·00560	±0·00624	±0·00005	±0·00106	±0·00008	±0·00159
(*I*) Jacobābād to Hyderābād	±0·00279	±0·00416	±0·00419	±0·00624	±0·00005	±0·00106	±0·00008	±0·00159

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It will be seen from the above that both lines fulfil the necessary conditions.

(ii). The probable error of the mean result per mile of simultaneous double levelling for the whole of India up to 1908 according to the formula

$$\text{P. E.} = \pm 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} \text{ is } \pm 0{\cdot}0042 \text{ foot}$$

(vide pages 375 and 377 of G. T. S. Volume XIX).

The following are the probable errors of the secondary lines levelled during last field season :—

(A)	± 0·0043 foot.	(E) (i)	± 0·0033 foot.
(C)	± 0·0027 „	(E) (ii)	± 0·0033 „
(D) (i)	± 0·0045 „	(E) (iii)	± 0·0043 „
(D) (ii)	± 0·0036 „	(F)	± 0·0028 „
(D) (iii)	± 0·0031 „	(G)	± 0·0027 „
(D) (iv)	± 0·0025 „	(H)	± 0·0034 „
(D) (v)	± 0·0028 „		

VIII. Nature of the country, weather conditions, etc.

The work throughout the season lay in flat or gently undulating country. The winter months were unusually mild and progress was rapid. On the other hand the early summer of 1921 was extremely hot and sultry ; in March, April and May, high winds, intense radiation, mirage and dust-storms reducing the hours of work and rate of out-turn considerably.

Owing to the areas in which Nos. 1 and 4 Detachments worked being largely desert, transport and supply questions presented some difficulties, while No. 3 Detachment was somewhat impeded by a number of river and canal crossings.

The detachments met with increased difficulties owing to the non-cooperation movement, and it is due to this that the cost is greater than it would otherwise have been. This was particularly the case in the U. P. where help though often promised was frequently not given. The officers in charge of the detachments are to be congratulated on having overcome these difficulties with a minimum of friction.

IX. Bench-marks. With the exception of the line Muttra-Mārwār-Pāli (B), practically no bench-marks could be cut on rock *in situ* as the lines lay through alluvial country. Reliance for permanency therefore depends almost entirely on embedded marks. In the section from Kambar to Sehwān (I) great difficulty was experienced in finding suitable objects on which to inscribe marks, and zinc plates were fixed on the roots of prominent trees. The experiments carried out in Dehra Dūn show that this method forms a good substitute for secondary marks.

A large number of G. T. tower stations were also connected. Table 4 shows these stations with their heights as derived from triangulation and spirit-levelling.

It is most regrettable that the engineers of the P. W. D., for whom the bench-marks are primarily intended, in many cases fail to realize the necessity of constructing the marks well in advance of the levelling operations, in order to allow time for settlement. A portion of the original programme allotted to No. 3 Detachment in the Ganges delta had to be cancelled owing to the marks not having been constructed by the time the detachment was ready to commence work. This work had been asked for by the local government and they had been given nearly a year's notice that it would be undertaken. A similar case happened with No. 4 Detachment, but here it was not of such importance as the bench-marks were mostly connected at the end of the season.

It may be noted also that engineers are the first to ask for new lines of levels and are frequently unwilling to undertake the least responsibility to see them preserved.

X. Health. The health of the several detachments was good, with the exception of Nos. 1 and 3. The former had a little sickness while No. 3 suffered considerably from malaria. One death occurred in the field and two men were invalided back to headquarters.

XI. Discussion of Results. Table 2 shows the check-levelling carried out during the season and Table 3 the results of revision levelling.

Muttra to Mārwār Pāli (B). The difference of the published dynamic heights of Muttra and Mārwār Pāli is 0·017 feet less than the difference obtained from last season's levelling. This is exceedingly small and has been dispersed between the two places in the new line.

Sārdā Canal Project area. (C, D & H) In the line from Pīlibhīt to Mailānī the terminal differences between levellers were large, probably owing to the following causes :—

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(i). The levelling followed the railway track through high grass and freshly cut forest. Consequent radiation made staff-readings, even at very short distances, extremely difficult to estimate.

(ii). Level No. 2625 was fitted with a rather unsatisfactory bubble and in the hands of an inexperienced leveller gave a steadily increasing difference. On the completion of this line the senior leveller used this instrument and the differences thereafter were never large.

The remainder of the work calls for no remarks.

Nadiā Rivers Scheme and Irrigation work.—

(A, E, F, G) The adjustments on lines A and E were small, that between Chākdaha and Jayrāmpur being less than one inch in 158·5 miles.

Line G was not so satisfactory, there being some 9 inches to disperse in 165 miles. With regard to this, the differences between the two levellers being consistent, the only conclusion that can be drawn is that the bench-marks have settled irregularly. In the opinion of the levellers this settlement took place shortly after the original levelling owing to their not having been constructed sufficiently long beforehand.

The crossing of the Ganges at Sāra (F) is interesting as it affords a check, by direct levelling over the Hardinge bridge on the old methods.

The river is wide, and three methods were originally employed—(1) Vertical angles (2) Modified target and (3) Tide pole (For description of these operations see Professional Paper No. 7, 1903, page 11).

It was unfortunate that direct comparison could not be made between the pillars since one of these has been destroyed; nevertheless it was possible to compare the differences between the embedded bench-marks B.M. 2/78 H and B.M. 7/78 H on either side of the river, as obtained by the various methods. The results are as follows:—

(*a*)	(Old.)	Vertical angles	5·457 feet.
(*b*)	(Old.)	Modified target	5·450 ,,
(*c*)	(Old.)	Tide pole	5·530 ,,
(*d*)	(New.)	Direct levelling	5·565 ,,

Most of the old bench-marks from Sāra to Nator have either been destroyed or disturbed by the dismantling of the metre-gauge line. New heights have therefore been given throughout. It was originally intended to close on B.M. 159/72 O, embedded at Manihāri, but check-levelling proved it to have suffered some change and the line was carried on to Rautāra (B.M.164/72 O), where check-levelling gave good results.

The adjustments were as follows:—

(a)	0·076	foot in	17·2	miles	between	BM8/79E and BM2/78H
(b)	0·626	,, ,,	179·8	,,	,,	BM2/78H ,, BM157/72O
(c)	0·024	,, ,,	1·2	,,	,,	BM156/72O and BM154/72O
(d)	0·026	,, ,,	9·3	,,	,,	BM153/72O ,, BM162/72O
(e)	0·003	,, ,,	3·3	,,	,,	BM162/72O ,, BM164/72O.

From these adjustments the old bench-mark at Nator BM 7/78D has received a new height, and the difference of 0·054 foot between the old and new heights has been distributed between it and Pārvatīpur BM 12/78 C.

Sukkur barrage project area. Jacobābād to Hyderābād (1).

The difference between the published heights of Jacobābād and Hyderābād is 96·306 feet, while that obtained by last season's levelling is 96·075 feet. The discrepancy between these two values has been distributed proportionately throughout the distance.

XII. Miscellaneous.

(*a*) *The new level net.* The programme laid down last year for the new level net has been carried out, and arrangements are in hand for the erection of bench-marks on the lines proposed for the next two years.

(*b*) *Levelling for earthquakes.* In consequence of the interesting results of the relevelment of the line from Silchar to Comilla, described in last year's Records Volume, arrangements have been made whereby the programme will be submitted annually to the Director of the Geological Survey, who has undertaken to make suggestion for the establishing of stable bench-marks on either side of Geological faults. This will enable lines to be revised after earthquakes have taken place and may lead to interesting results.

The lines that are concerned in the forthcoming programme are:—

(i) *In Cutch.* In the neighbourhood of Bhūj, three branch lines will be levelled at right angles to the main line which is closely parallel to the main fault.

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(ii) *Gooty to Ongole.* This line crosses a fault at right angles. At least four check-level bench-marks will be connected each at Giddalūr, Cumbum, and Podili.

(iii) *Surat to Dhūlia.* Four check-level bench-marks will be connected at Bārdoli, fort Songarh, Navāpur and Visarvadi.

(*c*) At the conclusion of last field season, an investigation was made by Lieut.-Colonel H. McC. Cowie, R. E., Offg. Superintendent of the Trigonometrical Survey, into the question of comparison of tapes at the commencement and end of a season. The results are being drawn up and will be published as an appendix to the handbook on levelling of precision.

(*d*) The following publications on levelling have been issued since last year's report.—

Handbook on "Levelling of Precision", revised by H. G. Shaw, Dehra Dūn, 1920.
Addenda slip to pamphlet 38.
Addenda slip to addenda pamphlet 39.
Addenda pamphlet 44.
Addenda slip to pamphlet 53.
New edition of pamphlet 54.
Addenda slip to addenda pamphlet 63.
Correction slips to addenda pamphlets 72, 73, 78, 79, 83.

The following pamphlets are affected by the levelling operations of last season :—

34 (10 Bms.), 35 (135 Bms.), 39 (11 Bms.), 40 (77 Bms.),
45 (183 Bms.), 53 (60 Bms.), 54 (155 Bms.), 62 (91 Bms.),
63 (401 Bms.), 72 (224 Bms.), 78 (159 Bms.), 79 (106 Bms.),

These data will be published in the following manner during 1921-22 :—

34, Addendum pages to pamphlet.
35, Addendum pages to pamphlet.
39, Addendum pages to Addendum pamphlet.
40, 45, 53, 54 } Addendum pages to pamphlet.
62, 1st Edition of pamphlet.
63, 2nd Edition, Addendum pamphlet.
72, Addendum pages to Addendum pamphlet.
78, 79 } 2nd Edition of pamphlet.

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TABLE I.—*Tabular statement of out-turn of work, season 1920-21.*

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions.				Total number of feet (Mean of both directions).		Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected.															Remarks.
										Primary.						Secondary.									
			Main-Line.	Extras and branch-lines.	Total.	Relevelled.				Rock-cut.	Protected.	Standard.		Primary stations of triangulation.		Embedded.		Rock-cut.		Inscribed.		P. W. D.		Railway.	
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Rises.	Falls.		Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	
1 (A) and 1 (B)	A. Tinpahār to Jiāganj	Nov. 1920	73 49 94	2 65 08	76 35 02	...	608·104	566·023	864	...	...	...	...	...	...	...	9	...	1	...	57	...	...	...	...	Simultaneous double levelling
		Dec. 1920	7 47 88	0 53 52	8 21 40	...	118·323	113·799	126																
		Totals Secondary	81 17 82	3 38 60	84 56 42	...	726·427	679·822	990	...	...	...	...	...	...	...	9	...	1	...	57	...	...	...	...	
	B. Muttra to Mārwār Pāli	Dec. 1920	35 31 88	2 06 50	37 38 38	...	212·041	265·373	385																	Fore and back double levelling of precision
		Jan. 1921	68 21 16	3 34 87	71 56 03	...	841·338	867·482	806																	
		Feb. 1921	56 65 84	7 76 06	64 61 90	...	841·033	696·413	737	...	...	1	1	...	3	1	33	...	53	5	201	...	...	...	...	
		Mar. 1921	58 41 63	7 73 95	66 35 58	2 78 71	878·475	715·742	771 39																	
		Apr. 1921	80 41 25	3 28 69	83 69 94	2 52 08	976·795	964·858	895 61																	
		May 1921	23 22 75	1 74 80	25 17 55	0 02 00	109·699	194·929	236																	
		Totals Primary	322 64 51	26 54 87	349 39 38	5 52 79	3859·381	3704·797	3930	...	...	1	1	...	3	1	33	...	53	5	201	...	...	...	...	

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TABLE I.—*Tabular statement of out-turn of work, season 1920-21.*—(*Continued*).

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions. Main-Line.	Extras and branch-lines.	Total.	Relevelled.	Total number of feet (Mean of both directions). Rises.	Falls.	Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected. Primary. Rock-cut. Old	Rock-cut. New	Protected. Old	Protected. New	Standard. Old	Standard. New	Primary stations of triangulation. Old	Primary stations of triangulation. New	Secondary. Embedded. Old	Embedded. New	Rock-cut. Old	Rock-cut. New	Inscribed. Old	Inscribed. New	P. W. D. Old	P. W. D. New	Irrigation. New	Railway. New	Remarks.
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.																						
2	C. Bareilly to Pilibhit	Oct. 1920	17 16 38	...	17 16 38	...	114·629	87·229	176	...	...	...	...	1	...	3	...	...	...	...	...	8	40	...	1	...	...	
		Nov. 1920	17 37 06	24 52 76	42 09 82	...	161·224	135·072	418																			
		Totals	34 53 44	24 52 76	59 26 20	...	275·853	222·297	594	...	...	...	...	1	...	3	...	...	...	...	...	8	40	...	1	...	...	
	D. (i) Pilibhit to Mailani	Nov. 1920	31 37 54	1 48 14	33 05 68	...	146·785	186·198	356	...	...	...	...	...	...	...	2	..	4	...	...	...	47	...	...	...	...	
		Dec. 1920	12 60 94	...	12 60 94	...	55·641	83·143	136																			
		Totals	44 18 48	1 48 14	45 66 62	...	202·426	269·341	492	...	...	...	...	...	...	...	2	...	4	...	...	...	47	...	...	...	...	
	D (ii) Shahjahanpur to Sitapur	Dec. 1920	54 14 26	5 13 22	59 27 48	...	312·277	305·712	610	...	...	...	...	2	...	...	3	...	11	...	...	6	82	...	6	19	1	
		Jan. 1921	53 51 80	2 64 60	56 36 40	...	208·555	276·501	554																			
		Totals	107 66 06	7 77 82	115 63 88	...	520·832	582·213	1164	...	...	...	...	2	...	...	3	...	11	...	...	6	82	...	6	19	1	
	D (iii) Sitapur to Lucknow	Jan 1921	44 66 08	10 56 56	55 42 64	...	234·231	246·237	498	...	...	...	...	1	...	...	3	1	10	...	...	5	70	...	...	16	...	
		Feb. 1921	45 28 94	2 63 46	48 12 40	...	360·221	402·619	470																			
		Totals	90 15 02	13 40 02	103 55 04	...	594·452	648·856	978	...	...	...	...	1	...	...	3	1	10	..	...	5	70	...	...	16	...	
	D (iv) Lucknow to Fyzabad	Feb. 1921	54 31 44	6 21 64	60 53 08	...	265·599	304·784	552	...	...	...	...	1	...	1	6	1	13	...	...	4	136	...	...	...	...	
		Mar. 1921	86 75 94	9 54 68	96 50 62	...	370·072	395·800	804																			
		Totals	141 27 38	15 76 32	157 23 70	...	635·671	700·584	1356	...	...	...	...	1	...	1	6	1	13	...	...	4	136	...	...	...	...	

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TABLE I.—*Tabular statement of out-turn of work, season 1920-21.*—(*Continued*).

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions.				Total number o feet (Mean of both directions).		Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected.																Remarks.
										Primary.						Secondary.										
			Main-Line.	Extras and branch-lines.	Total.	Relevelled.				Rock-cut.	Protected.	Standard.		Primary stations of triangulation.		Embedded.		Rock-cut.		Inscribed.		P. W. D.		Irrigation.	Railway.	
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Rises.	Falls.		Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	New	New	
2	D (v) Sultānpur to Allahābād	March 1921	25 12 40	...	25 12 40	...	107·956	119·723	214	..	...	2	...	...	...	1	6	...	...	9	42	...	...	17	..	
		April 1921	40 07 70	1 63 00	41 70 70	...	343·132	345·325	399																	
		Totals	65 20 10	1 63 00	67 03 10	...	451·088	465·048	613	...	...	2	...	...	...	1	6	...	...	9	42	...	...	17	...	
		Grand Totals Secondary	483 40 48	65 38 06	548 78 54	...	2680·322	2888·339	5197	..	...	7	...	4	14	3	44	...	...	32	417	...	7	52	1	
3	E (i) & (ii) Chākdaha to Jayrāmpur	Nov. 1920	53 61 20	16 17 48	69 78 68		335·632	330·935	640																	
		Dec. 1920	79 40 60	2 71 46	82 32 06	...	443·009	435·776	670	...	...	...	...	...	8	3	13	...	...	10	88	...	2	...	1	
		Jan. 1921	23 21 46	3 78 70	27 20 16		125·782	127·993	208																	
		Totals	156 43 26	23 07 64	179 50 90	..	904·423	894·704	1518	...	..	...	...	...	8	3	13	...	...	10	88	...	2	...	1	
	E (iii) Berhampore to Tinpahār Portion of Berhampore to Jiāganj	Dec. 1920	16 04 96	14 32 50	30 37 46	...	106·946	99·657	256	...	...	...	...	...	...	...	5	...	...	...	15	...	...	...	...	
		Totals	16 04 96	14 32 50	30 37 46	...	106·946	99·657	256	...	...	...	...	...	...	...	5	...	...	...	15	...	...	...	...	
	F. Porādaha to Rautāra	Jan. 1921	76 58 80	...	76 58 80	...	401·423	385·677	564																	
		Feb. 1921	90 20 48	14 24 70	104 45 18	...	537·423	511·860	848	...	...	...	...	...	2	10	14	...	...	23	72	...	1	...	...	
		Mar. 1921	49 66 56	...	49 66 56	...	233·039	205·076	352																	
		Totals	216 65 84	14 24 70	231 10 54	...	1171·885	1102·613	1764	...	...	...	...	...	2	10	14	...	...	23	72	...	1	...	...	

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TABLE I.—*Tabular statement of out-turn of work, season 1920-21.*—(*Concluded*).

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions. Main-Line.	Extras and branch lines.	Total.	Relevelled.	Total number of feet (Mean of both directions). Rises.	Falls.	Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected. Primary. Rock-cut. Old	Protected. New	Standard. Old	New	Primary stations of triangulation. Old	cw	Secondary. Embedded. Old	New	Rock-cut. ld	New	Inscribed. Old	New	P. W. D. Old	New	Irrigation. Old	New	Remarks.
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls. hs.Lks.	Mls.Chs.Lks.	Rises.	Falls.																		
3	G. Darbhangā to Bagahā	Mar. 1921	45 10 62	4 29 8	49 39 80	...	206·740	162·708	366																	
		Apr. 1921	85 28 04	9 55 42	95 03 46	...	385·829	305·771	668	...	..	...	...	2	7	...	23	...	...	4	127	...	...	...	...	
		May 1921	34 48 14	1 23 30	35 71 44	...	179·370	174·306	258																	
		Totals	165 06 80	15 27 90	180 34 70	...	771·939	642·785	1292	...	...	...	...	2	7	...	23	...	...	4	127	...	...	..	...	
		Grand Totals Secondary	554 40 86	67 12 74	621 53 60	...	2955·193	2739·759	4830	...	...	...	...	2	17	13	55	...	..	37	302	...	3	...	1	
4	H. Shāhjahānpur to Baghauli	Oct. 1920	7 26 00	1 06 34	8 32 34	...	77·871	98 894	126	...	...	1	...	...	...	...	1	...	...	6	5	...	...	...	...	
		Nov. 1920	48 63 62	2 19 24	51 02 86	1 17 45	311·632	358·210	702	...	...	...	...	...	...	...	6	...	...	...	37	...	...	...	...	
		Totals Secondary	56 09 62	3 25 58	59 35 20	1 17 45	389·503	457·104	828	...	...	1	...	...	...	...	7	...	...	6	42	...	...	...	...	
	I. Jacobābād to Hyderābād	Dec. 1920	52 48 98	3 59 91	56 28 89	...	89·494	121·954	541	...	...	1	...	...	...	1	...	...	...	4	8	...	...	10	...	
		an. 1921	87 57 24	3 09 62	90 66 86	4 72 82	267·457	286·280	966	...	...	...	...	2	...	...	5	...	...	...	29	...	...	18	...	
		Feb. 1921	78 23 17	4 24 91	82 48 08	10 05 16	332·634	350·285	745	...	...	...	...	...	...	1	10	...	2	...	68	...	...	6	...	
		Mar. 1921	105 04 91	0 62 85	105 67 76	5 11 05	639·284	657·360	1002	1	...	1	...	...	...	...	9	...	...	7	73	1	...	2	...	
		Apr. 1921	...	...	...	3 56 09	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	
		Totals Primary	323 54 30	11 77 29	335 51 59	23 65 12	1328·869	1415·879	3254	1	...	2	...	2	...	2	24	...	2	11	178	1	...	36	...	

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TABLE II.—Check-Levelling.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (Check—Original). The sign + denotes that the height was greater and the sign − less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1920-21.	
			Miles.	Feet.		Feet.	Feet.
B. *At Muttra.*							
25	54 E	Standard Bench-mark at Muttra	0·0	0·000	1905-06	0·000	0·000
40	„	Verandah of Kachahri, Muttra	0·0	+ 2·035	1912-13	+2·035	+0·000
21	„	Parapet of culvert	0·9	+ 5·680	1905-06	+5·694	+0·014
24	„	Platform of Muttra junc: R. S.	2·0	+21·583	„	+21·586	+0·003
B. *At Mārwār Pāli.*							
17	45 O	Embedded, Mārwār Pāli R. S.	0·0	0·000	1907-1909	0·000	0·000
16	„	Blocks of masonry near M. S. 182	0·3	+ 1·459	„	+1·445	−0·014
18	„	„ „ „ „ 184	2·1	+18·501	„	+18·509	+0·008
C. *At Bareilly.*							
53	53 P	At Cantt. church, Bareilly	0·0	0·000	1919-20 1867-69	0·000	0·000
359 (54)	„	Well near junc: of roads from church and station Hospital	0·5	+ 1·957	1919-20	+1·957	0·000
358 (284)	„	Culvert 1 furlong NE. of Fort	0·8	+ 2·735	„	+2·730	−0·005
357	„	At G. P. O.	1·2	+ 2·445	„	+2·438	−0·007
356 (56)	„	Well opposite Dinshaw Sorabjee's shop	1·3	+ 3·657	„	+3·637	−0·020
57	„	Standard Bench-mark	1·5	+ 4·876	1905-06	+4·871	−0·005
58	„	At Commissioner's office	2·0	+ 6·523	„	+6·534	+0·011
D (ii). *At Shāhjahānpur.*							
11	54 M	Standard Bench-mark	0·0	0·000	1905-06	0·000	0·000
10	„	St. Mary's church	0·0	− 2·363 − 2·355	1867-69 1919-20	−2·358	+0·005 −0·003
41	„	General Mile-pillar	0·3	− 1·813 − 1·823	1905-06 1919-20	−1·833	−0·020 −0·010
60	„	Post and telegraph office	0·4	− 2·162	1919-20	−2·168	−0·006
59	„	Bridge No. $\frac{1}{4}$	0·7	− 4·751	„	−4·750	+0·001
58	„	Bridge No. 36 (old)	0·7	− 3·609	„	−3·614	−0·005

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TABLE II—Check-Levelling.—(*Continued*).

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (Check—Original). The sign + denotes that the height was greater and the sign − less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1920-21.	
			Miles.	Feet.		Feet.	Feet.
D (ii) and (iii). *At Sitāpur.*							
23	63 A	Collector's Kachahri	0·0	0·000	1867-69	0·000	0·000
26	,,	Standard Bench-mark	0·1	+ 0·922	1905-06	+ 0·917	−0·005
27	,,	Stone Prism	0·3	− 0·382	,,	− 0·394	−0·012
20	,,	Mirza Abbas Beg's well	0·3	+ 2·174	1867-69	+ 2·165	−0·009
D (iii) and (iv). *At Lucknow.*							
6	63 B	District Judge's court	0·0	0·000	1867-69	0·000	0·000
7	,,	Christ church	1·5	− 1·388	,,	− 1·377	+0·011
97	,,	Overhead bridge near Ry. officers' quarters	2·6	+35·538	1905-06	+35·555	+0·017
8	,,	Embedded (block-stone)	2·8	+18·821	1867-69	+18·835	+0·014
96	,,	Standard Bench-mark	2·8	+28·691	1909-10	+28·700	+0·009
D (iv). *At Fyzābād.*							
18	63 J	Standard Bench-mark	0·0	0·000	1905-06	0·000	0·000
12	,,	C. B. pillar near post office	0·3	+ 0·247	1868-70	+ 0·241	−0·006
17	,,	Embedded (block-stone)	0·4	− 1·742	,,	− 1·772	−0·030*
13	,,	Pillar marked $\overset{330\cdot53}{\oplus}$	0·5	− 0·550	1905-06	− 0·552	−0·002
14	,,	,, $\overset{327\cdot05}{\oplus}$	1·0	− 4·078	,,	− 4·245	−0·167*
15	,,	St. Andrew's church	1·3	− 1·699	,,	− 1·717	−0·018
D (v). *At Allahābād.*							
58	63 G	Embedded at fort	0·0	0·000	1898-99	0·000	0·000
57	,,	Sentry box	0·1	− 0·347	,,	− 0·296	+0·051†
45	,,	Lala Manohar Dass' well	0·2	−13·282	,,	−13·261	+0·021
46	,,	Bridge near railway lines	1·3	−18·657	1905-06	−18·612	+0·045*
47	,,	Cattle trough near Govt. house	1·9	− 8·971	,,	− 8·850	+0·121*
52	,,	Stand of water pipe	2·8	+10·002	,,	+ 9·529	−0·473‡

* Altered. † Inscribed slab quite loose. ‡ Sunk.

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TABLE II.—CHECK-LEVELLING.—(*Continued*).

Descrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (Check—Original). The sign + denotes that the height was greater and the sign— less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1920-21.	
			Miles.	Feet.		Feet.	Feet.
		D (v). *At Allahābād (Concld.)*					
51	63 G	Standard B.M. at Scotch kirk	4·6	+19·284	1905-06	+19·240	−0·044
53	,,	Culvert near Muir central college	3·3	+11·582	,,	+11·627	+0·045*
54	,,	Suitors' waiting shed	3·8	+14·875	,,	+14·960	+0·085*
55	,,	Standard B.M. at Collector's kachahri	3·9	+16·632	,,	+16·667	+0·035†
		E (i). *At Kānchrāpāra, part of line 77 (Howrah to Rāmganj).*					
387	79 B	Embedded, Kānchrāpāra ...	0·0	0·000	1882-83 1894-95	0·000	0·000
388	,,	Bridge ...	0·5	− 4·499	,,	−4·489	+0·010
389	,,	,, ..	2·1	− 3·969	,,	−3·971	−0·002
390	,,	,, ...	4·0	− 2·335	,,	−2·324	+0·011
36	79 H	Platform, Madanpur ...	4·8	+ 4·052	,,	+4·006	−0·046
37	,,	Bridge ...	6·2	+ 2·919	,,	+2·938	+0·019
38	,,	,, ...	7·8	+ 5·219	,,	+5·246	+0·027
39	,,	,, ...	9·6	+ 7·324	,,	+7·372	+0·048
40	,,	Embedded, Chākdaha ...	10·5	+ 6·628	,,	+6·614	−0·014
		E (ii). *At Jayrāmpur, part of line 77 (Howrah to Rāmganj).*					
68	79 A	Embedded, Jayrāmpur ...	0·0	0·000	1882-83 1894-95	0·000	0·000
69	,,	Bridge ...	1·4	−12·887	,,	−12·832	+0·055
70	,,	,, ...	3·3	− 6·215	,,	− 6·241	−0·026
71	,,	,, ...	5·0	− 6·118	,,	− 6·127	−0·009
		(G). *At Darbhangā, part of line 71 (Gorakhpur to Purnea).*					
49	72 F	Chotaipati T. S.	0·0	0·000	1870-71-72	0·000	0·000
46	,,	*Shiwala* ...	4·2	+ 6·347	,,	+ 6·354	+0·007
41	,,	*Masjid* ...	10·2	+11·424	,,	+11·387	−0·037
		(G). *At Bagahā, part of line 71 (Gorakhpur to Purnea).*					
5	72 A	Bakwa T. S.	0·0	0·000	1870-71-72	0·000	0·000
1	,,	Well ...	7·3	+ 8·410	,,	+ 8·363	−0·047
2	,,	*Shiwala* ...	8·0	+ 8·456	,,	+ 8·391	−0·065

* Altered. † Stone top broken and repaired with cement.

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TABLE II—Check Levelling.—(*Concluded*).

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (Check—Original). The sign + denotes that the height was greater and the sign − less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1920-21.	
			Miles.	Feet.		Feet.	Feet.
		(H). *At Shāhjahānpur.*					
11	54 M	Standard, Shāhjahānpur ...	0·0	0·000	1905-06	0·000	
10	,,	St. Mary's church ...	0·0	− 2·363	1867-69	−2·356	+0·007
41	,,	General Mile-pillar ...	0·3	− 1·813	,,	−1·829	+0·016
60	,,	Post and telegraph office ...	0·4	− 2·162	1919-20	−2·164	−0·002
59	,,	Bridge No. $\frac{3}{1}$ on stn. road ...	0·7	− 4·751	,,	−4·748	+0·003
58	,,	Bridge No. 36	0·7	− 3·609	,,	−3·614	−0·005
		(I). *At Jacobābād.*					
23	39 D	Standard, Jacobābād ...	0·0	0·000	1909-10	0·000	
24	,,	Iron plug in Executive Engineer's office ...	0·0	− 1·420	,,	−1·409	+0·011
20	,,	Masjid of Lang Shāh's *takia* ...	0·5	+ 0·630	,,	+0·659	−0·001
19	,,	Railway stn., Jacobābād ...	1·0	+ 2·109	,,	+2·106	−0·003
18	,,	Embedded B. M., Jacobābād ...	1·1	− 6·026	,,	−6·033	−0·007
		(I). *At Hyderābād.*					
161	40 C	Standard, Hyderābād ...	0·0	0·000	1904-06	0·000	
160	,,	St. Thomas' church ...	0·0	+ 0·625	,,	+0·625	0·000
159	,,	Travellers' bungalow ...	0·4	— 0·542	,,	−0·544	−0·002
31	,,	Old Kachahri ...	0·6	+ 7·864	1909-10	+7·861	−0·003
157	,,	*Vidyalaya* ...	0·7	− 5·347	1904-05-06	−5·350	−0·003

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TABLE III.—Revision Levelling.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark.	Difference between orthometric heights, above (+) or below (−) the starting bench-mark.			Difference (Revision − Original). The sign + denotes that the height was greater and the sign − less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		From published heights	Date of Original levelling.	From revision 1920-21 (Unadjusted).	
			Miles.	Feet.		Feet.	Feet.
		C. Revision of Branch line 64 A (Bareilly to Pīlībhīt).					
53	53 P	G.T.S. ⊙ B.M. at Cantt. church, Bareilly	0·0	0·000	1867-68	0·000	0·000
93-112	"	...	...	...	...	...	... *
113	"	Persādi Teli's well, Nawābganj *tahsīl*	21·6	+ 26·157	"	+ 26·179	+0·022†
114-125	"	...	...	...	...	...	... *
126	"	Ataria Tower station ...	29·2	+ 59·759	"	+ 59·808	+0·049†
127-128	"	...	...	...	...	...	... *
129	"	Kaliānpur Tower station ...	30·1	+ 69·280	...	+ 69·289	+0·009†
130-141	"	...	...	...	...	...	... *
142	"	Umra Tower station ...	49·5	+ 50·416	...	+ 50·322	−0·094†
143	"	...	...	...	...	...	... *
144	"	At Jama Masjid, Pīlībhīt ...	34·7	+ 53·527	...	+ 53·472	−0·055†
		F. Revision of line Porādaha to Nator, part of line 77 (Howrah to Rāmganj).					
4	79 E	Embedded, Porādaha ...	0·0	0·000	1882-83 1894-95 1899-1900	0·000	0·000
3	"	Bridge ...	0·2	− 11·178	"	− 11·169	+0·009
8	"	" ...	0·7	− 4·351	"	− 4·332	+0·019
6‡	"	" ...	9·1	+ 2·452	"	+ 2·378	−0·074
7§	"	" ...	11·5	+ 5·430	"	+ 5·259	−0·171
2	78 H	Embedded, Dāmukdia ...	17·9	+ 1·525	"	+ 1·468	−0·057
3	"	Iron bolt ...	18·2	+ 2·932	"	+ 2·792	−0·140
5	"	Iron rail ...	18·3	+ 3·521	"	+ 3·416	−0·105
7	"	Embedded, Sāra ...	25·3	+ 6·973	"	+ 7·033	+0·060
10	"	Bridge ...	31·7	+ 3·527	"	+ 3·544	+0·017
11	"	Embedded, Gopālpur ...	33·1	+ 5·557	"	+ 5·608	+0·051
1	78 D	Bridge ...	35·3	+ 4·137	"	+ 4·161	+0·024
2	"	" ...	37·7	+ 5·139	"	+ 5·106	−0·033
3	"	Embedded, Mālanchi ..	40·7	+ 8·432	"	+ 8·340	−0·092
4	"	Bridge ...	42·2	+ 7·399	"	+ 7·492	+0·093
5	"	" ...	43·4	+ 7·730	"	+ 7·874	+0·144
6	"	" ...	45·9	+ 6·084	"	+ 6·253	+0·169
7	"	Embedded, Nator ..	48·4	+ 5·530	"	+ 5·635	+0·105
		F. Revision of line Manihāri to Katihār, part of line 77 B (Pārbatīpur to Manihāri).					
159	72 O	Embedded, Manihāri ...	0·0	0·000	1899-1900	0·000	0·000
158	"	Bridge ...	4·1	− 0·431	"	− 0·326	+0·105
157	"	" ...	4·8	− 2·070	"	− 1·939	+0·131
156	"	" ...	9·0	− 1·649	"	− 1·532	+0·117
155	"	Embedded, Manshahi ...	9·8	+ 1·264	"	+ 1·180	−0·084
154	"	Bridge ...	10·2	− 0·048	"	+ 0·074	+0·122
153	"	" ...	11·4	+ 0·097	"	+ 0·240	+0·143
152	"	" ...	12·8	− 0·112	"	− 0·018	+0·094
151	"	" ...	13·6	+ 1·021	"	+ 1·125	+0·104
150	"	Embedded, Katihār ...	15·1	+ 1·300	"	+ 1·300	0·000

* Destroyed. † Unaltered. ‡ This bench-mark falls in degree sheet 79 A and is numbered 230.
§ This bench-mark falls in degree sheet 78 D and is numbered 88.

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TABLE III.—Revision Levelling.—(*Concluded*).

Discrepancies between the old and new heights of bench-marks.

Beuch-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark.	Difference between orthometric heights, above (+) or below (−) the starting bench-mark.			Difference (Revision—Original). The sign + denotes that the height was greater and the sign— less in 1920-21 than when originally levelled.
Number.	Degree Sheet.	Description.		From published heights.	Date of Original levelling.	From revision 1920-21 (Unadjusted).	
			Miles.	Feet.		Feet.	Feet.
		F. Revision of line Katihār to Rautāra, Part of line 77 C (Katihār to Anchrā Ghāt).					
150	72 O	Embedded, Katihār ...	0·0	0·000	1899-1900	0·000	0·000
160	,,	Bridge ...	0·8	− 0·649	,,	− 0·582	+0·067
161	,,	,, ...	3·6	+ 2·679	,,	+ 2·779	+0·100
162	,,	,, ...	5·5	+ 4·168	,,	+ 4·338	+0·170
163	,,	,, ...	7·8	+ 7·529	,,	+ 7·675	+0·146
164	,,	Embedded, Rautāra ..	8·8	+ 10·665	,,	+ 10·833	+0·168
		H. Branch-line 64 G (Shāhjahānpur to Baghauli).					
61	54 M	Jawala Persad house gate at Shāhjahānpur ...	0·7	− 15·090	1919-20	− 15·099	−0·009*
		I. Part of Main line 101 (Jacobābād to Hyderābād).					
23	39 D	Standard, Jacobābād ...	0·0	0·000	1909-10	0·000	...
21	,,	Victoria clock Tower at Jacobābād ...	0·6	+ 2·740	,,	+ 2·731	−0·009*
22	,,	Municipal office ...	0·9	− 0·738	,,	− 0·771	−0·033†
2	35 M	Sojra Tower station ...	106·1	− 9·562	1858-60	− 10·596	−1·034†
1	,,	Lokha Tower station ...	118·5	− 28·870	,,	− 29·461	−0·591†
3	35 N	Embedded B M. at Gularo ...	212·8	− 69·020	,,	− 69·554	−0·534†
38	40 C	Zero of Kotri gauge ...	319·7	− 116·164	1904-06	−116·405	−0·241†
39	,,	Wooden water gauge ...	319·7	− 116·767	,,	−116·984	−0·217*
35	,,	$\frac{\text{H.F.L. 6680}}{1894}$ near Flotilla office	320·0	− 117·611	,,	−117·786	−0·175†
34	,,	Gidu Bandar bridge ...	320·6	− 92·825	,,	− 93·037	−0·212*
33	,,	Railway bridge near T. P. $\frac{110}{20}$ ...	322·0	− 100·687	,,	−100·908	−0·221*

* Unaltered. † New value and number given.

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TABLE IV.

List of Great Trigonometrical Survey Stations connected by Spirit-levelling, Season 1920-21.

Name of station.	Height above mean sea-level			Difference Δ—S.L.H.	Remarks.
	New spirit-levelling	Old spirit-levelling	Triangulation		
	Feet.	Feet.	Feet.	Feet.	
Series 3. Amūa Meridional.					
1. Nimkār T.S. ...	465·185	...	...	...	The station no longer corresponds with that described in Triangulation pamphlet 63A. A comparison of heights is therefore impossible.
2. Asu T.S. ...	450·791	...	450·0	−0·8	Connected to ground mark-stone at top of mound. (*Vide* Triangulation pamphlet 63A).
3. Etora T.S. ...	427·229	...	...	...	The station appears to be new and no comparison is possible. (*Vide* Triangulation pamphlet 63B).
Series 6. Great Arc Meridional. Section 24° to 30°.					
4. Alīpur H.S. ...	1348·847	...	1351·0	+2·2	Connected to upper mark-stone. (*Vide* Triangulation pamphlet 54A).
5. Madhoni H.S. ...	709·323	...	714·0	+4·7	Connected to ground mark-stone (*Vide* Triangulation pamphlet 54E).
Series 12. Karāra Meridional.					
6. Tauli T.S. ...	399·319	...	405·0	+5·7	Connected to mark-stone 24 feet above that at base of pillar. (*Vide* Triangulation pamphlet 63F).
7. Sora T.S. ...	400·482	...	409·0	+8·5	Connected to mark-stone 24 feet above that at base of pillar. (*Vide* Triangulation pamphlet 63F).
8. Munai T.S. ...	390·491	...	392·0	+1·5	Connected to mark-stone 20 feet above that at base of pillar. (*Vide* Triangulation pamphlet 63F).
Series 16. Calcutta Meridional.					
9. Imāmnagar T.S. ...	49·498	...	55·0	+5·5	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 78D).
10. Dilālpur T.S. ...	76·727	...	92·0	+15·3	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 78D).
11. Onāli T.S. ...	129·815	..	151·0	+21·2	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 78D).
12. Madhupur T.S. ...	52·562	...	59·0	+6·4	Connected to ground level mark-stone (*Vide* Triangulation pamphlet 79A).
13. Kistonagar T.S. ...	38·873	...	49·0	+10·1	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 79A).

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TABLE IV.—(*Continued*).

List of Great Trigonometrical Survey Stations connected by Spirit-levelling, Season 1920-21.

Name of station.	Height above mean sea-level			Difference Δ—S.L.H.	Remarks.
	New spirit-levelling	Old spirit-levelling	Triangulation		
	Feet.	Feet.	Feet.	Feet.	
Series 16. Calcutta Meridional.—(Concluded).					
14. Gobipur T.S. ...	40·796	...	47·0	+6·2	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 79A).
15. Bahādurpur T.S. ...	39·881	...	43·0	+3·1	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 79A).
16. Beliaiti T.S. ...	27·544	...	28·0	+0·5	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 79A).
17. Teragari T.S. ...	47·990	...	55·0	+7·0	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 79A).
Series 19. Gurwāni Meridional.					
18. Rāhet T.S.					
(Ground level) ...	342·549	342·549	341·5	−1·0	*Vide* Triangulation pamphlet 63 J.
(Upper mark) ...	368·006	...	367·0	−1·0	
19. Rarauli T.S. ...	345·574	...	349·0	+3·4	Connected to mark-stone 16 feet above that at base of pillar. (*Vide* Triangulation pamphlet 63 J).
20. Sirwāra T.S. ...	333·989	...	340·0	+6·0	Connected to mark-stone 16 feet above that at base of pillar. (*Vide* Triangulation pamphlet 63 J).
Series 20. North-East Longitudinal.					
21. Ataria T.S. ...	618·486	618·486	628·0	+9·5	Ground level mark-stone. (*Vide* Triangulation pamphlet 53 P).
22. Kaliānpur T.S. ...	628·007	628·007	633·0	+5·0	Upper mark-stone. (*Vide* Triangulation pamphlet 53 P).
23. Umra T.S. ...	609·143	609·143	613·0	+3·9	Upper mark-stone. (*Vide* Triangulation pamphlet 53 P).
24. Shāhgarh T.S. ...	634·512	...	635·0	+0·5	Connected to mark-stone 12 feet above the lowest mark-stone. (*Vide* Triangulation pamphlet 62 D).
25. Udepur T.S. ...	589·847	...	588·0	−1·8	Connected to mark-stone 7 feet above the lowest mark-stone. (*Vide* Triangulation pamphlet 62 D).
26. Karāi T.S. ...	556·498	...	552·0	−4·5	Connected to mark-stone about 20 feet above the surrounding ground level and probably corresponds to that described as 14 feet above the lowest. (*Vide* Triangulation pamphlet 62 D).

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TABLE IV.—(*Continued*).

List of Great Trigonometrical Survey Stations connected by Spirit-levelling, Season 1920-21.

Name of station.	Height above mean sea-level			Difference Δ—S.L.H.	REMARKS.
	New spirit-levelling	Old spirit-levelling	Triangulation		
	Feet.	Feet.	Feet.	Feet.	
Series 20. North-East Longitudinal.—(Concluded).					
27. Kokra T.S. ..	516·079	...	505·0	−11·1	Connected to mark-stone 12 feet above the lowest mark-stone. (*Vide* Triangulation pamphlet 62 D).
28. Saidhari T.S. ...	492·263	...	493·5	+1·2	Connected mark-stone is 12 feet above that at base of pillar (481·5). (*Vide* Triangulation pamphlet 63 A).
29. Bakwa T.S.* ...	...	284·192	...	...	Ground level mark-stone (*Vide* Triangulation pamphlet 72 A).
30. Rāmnagar T.S. ...	309·078	...	312·0	+2·9	Connected to ground level mark-stone (*Vide* Triangulation pamphlet 72 A).
31. Tarharwa T.S. ...	270·614	...	274·0	+3·4	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 72 A).
32. Sikta T.S. ...	262·895	...	267·0	+4·1	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 72 A).
33. Harnāhi T.S. ...	245·260	...	249·0	+3·7	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 72 B).
34. Sinaria T.S. ...	266·845	...	269·0	+2·2	Connected to top mark-stone. (*Vide* Triangulation pamphlet 72 F).
35. Humaunpur T.S. ...	186·287	...	192·0	+5·7	Connected to ground level mark-stone. (*Vide* Triangulation pamphlet 72 F).
36. Shāhpur T.S. ...	190·695	...	198·0	+7·3	Connected to top mark-stone. (*Vide* Triangulation pamphlet 72 F).
Series 27. N. Pārasnāth Meridional.					
37. Chotaipati T.S.* ...	..	154·303	...	..	Ground level mark-stone. (*Vide* Triangulation pamphlet 72 F).
Series 32. Great Indus.					
38. Sojra T.S. ...	172·331	173·289	173·0	+0·7	Connected to upper mark-stone. (*Vide* Triangulation pamphlet 35 M).
39. Lakha T.S. ...	153·475	153·981	154·4	+0·9	Connected to ground level mark-stone (*Vide* Triangulation pamphlet 35 M).

* A difference of 0·735 foot has been adjusted between Bakwa T.S. and Chotaipati T.S., which form the terminals of the line Darbhangā to Bagahā.

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TABLE IV.—(*Concluded*).

List of Great Trigonometrical Survey Stations connected by Spirit-levelling, Season 1920-21.

Name of station.	Height above mean sea-level			Difference Δ—S.L.H.	Remarks.
	New spirit-levelling	Old spirit-levelling	Triangulation		
	Feet.	Feet.	Feet.	Feet.	
Series 33. Rahūn Meridional.					
40. Bānskho H.S. ...	1878·079	...	1870·0	−8·1	Connected to upper mark-stone (*Vide* Triangulation pamphlet 54 B).
Series 48. East Calcutta Longitudinal.					
41. Ghatigāchhi T.S. ...	31·760	...	33·0	+1·2	Connected to ground level mark-stone (*Vide* Triangulation pamphlet 79 A).

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MAGNETIC SURVEY.

By E. C. J. Bond.

Personnel of No. 18 Party.

Class I Officer.

Mr. E. C. J. Bond, V. D., in charge.

Class II Officer.

Mr. N. R. Mazumdar.

Upper Subordinate Service.

Mr. B. B. Shome.
„ H. C. Banerjee, B. A.

Lower Subordinate Service.

2 Magnetic Observers.
10 Computers, etc.

The present report on the work of the magnetic party in 1920-21 comprises:—

I.—An account of the work during the field and recess seasons.

II.—A note on each of the observatories.

III.—Tables of the mean values of the magnetic elements, dates of magnetic disturbances, and hourly means and diurnal inequality of the magnetic elements at observatories in 1920.

I.—Work during the field and recess seasons.

1. *Work during the field season.*—Complete sets of magnetic observations were taken at the Dehra Dūn and Toungoo observatories for the comparison of instruments. The Alībāg and Kodaikānal observatories, under the control of the Meteorological Department, were also visited by the officer in charge for the same purpose.

Double sets of declination, dip and horizontal force observations were taken this field season at the six repeat stations—Quetta, Karāchi, Bīna, Dibrugarh, Barrackpore and Waltair. It is intended to determine the magnetic elements at these stations annually in order to obtain better indications of the annual changes in these elements, as explained below.

It was considered at first that the average annual changes in the magnetic elements could be derived with sufficient accuracy from the observations taken every five years at all the 80 repeat stations in India; since, however, there is evidence that the secular changes in these elements are subject to marked changes in their rate of progression at various times in different parts of India, it is now considered necessary to supplement the 5-yearly observations by annual observations at six of the repeat stations, suitably situated at even distances apart, with the object of ascertaining in which particular year, during the 5-year period an appreciable change in the secular variation occurred in any area, so that it may be possible to determine with greater accuracy the rate of average annual change which the magnetic elements undergo from time to time in various parts of the country.

During the field season simultaneous observations were taken at the Colāba and Alībāg observatories, about 18 miles apart, to determine the difference in the horizontal force between these places.

It was considered advisable this year to take these observations as a check on the difference derived from the independent comparative observations made with the Survey field instruments at Colāba in 1906, before magnetic work was discontinued at that observatory, and the earliest comparative observations taken, in 1907, at Alībāg, so as to make sure that the constants applied to the observations in 1906 and 1907 for the Colāba and Alībāg instruments had been satisfactorily determined.

Since it was decided to revise the constants of all the instruments, as reported last year, it was necessary also to examine and adjust those of the Colāba and Alībāg instruments in order to preserve uniformity in the reductions and to obtain satisfactory determinations of the horizontal force at Colāba and Alībāg in terms of the Survey standard at Dehra Dūn to permit of interpolating the disturbance and diurnal inequality corrections from the results of these observatories in the final reduction of the field observations to epoch.

Without the simultaneous observations taken this year, as a check, at Colāba and Alībāg, it seemed difficult to accept the comparative results obtained through the field instruments in 1906 and 1907, which do not afford a direct means of determining the difference in the horizontal force between these observatories.

Unfortunately, the results of the recent comparisons and those of 1906 and 1907 are not in good agreement and the only other way of testing the quality of the results of the latter comparisons was to plot the monthly mean values of the horizontal force at Colāba and Alībāg respectively for the years 1906 and 1907 and for subsequent years at Alībāg only, after a careful adjustment of the constants of all the instruments, and from the plotted curves to ascertain what anomaly, if any, existed in them. It was most satisfactory to find that the curves of the plotted monthly mean values of the horizontal force at Colāba and

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Alībāg meet at a common point, when both are reduced to terms of the standard, and are in good accord with the leading features of the corresponding curves at other observatories, which is evidence in favour of the correct constants having been determined for the Colāba and Alībāg instruments in 1906 and 1907, and this evidence is further strengthened by the consistency, throughout, of the values of the differences between the instruments of each of the two observatories and the Survey standard.

From the evidence given above the natural inference would be that the recent simultaneous observations are faulty. This, however, is not the case so far as the observations themselves are concerned, as the quality of the results and the accordant values of the instrumental differences in these comparisons show. The Absolute House at Colāba, where magnetic observations were taken originally and where the simultaneous observations were also taken this year, had undergone some alterations when in use as an office after 1906 and this has probably effected a change in the magnetic condition of the building and is most likely the cause of the non-agreement of the recent comparisons with those of 1906 and 1907.

The data required for the investigation of the Colāba and Alībāg results were obtained from the original records of 1901 to 1920, with the consent of the Director of these observatories to whom thanks are due for kindly permitting access to the records.

The computations, which have entailed a good deal of labour, were taken in hand during the latter part of the field season and have been completed during the recess.

The staff of the party was employed during the field season on the revision of the reduction of observations to epoch and in the computation of the observations received from the several observatories.

2. *Work during the recess.*—The computation of the observations taken at repeat stations and at observatories for the comparison of instruments, and the computation and tabulation of the provisional values of declination, dip, horizontal force and vertical force at the three observatories Dehra Dūn, Toungoo and Kodaikānal for 1920 have been completed. The mean values of these elements for the year, derived from the measurement of traces of all available days, excluding those of great disturbance, are given in Table III at the end of the report.

Publication of the results of the magnetic survey.—The reduction of the observations at the field and repeat stations to the epochs 1909·0 and 1920·0, which was last year reported to be under revision, is now well advanced and will be completed about the end of the year. The necessary charts and tables of results, etc., will then be taken in hand for the Magnetic volume which it is hoped will be ready for publication by the middle of next year.

Great Magnetic Storm.—A magnetic storm of great intensity, which interrupted the working of the telegraphs in India, was recorded at the observatories from the 13th to the 17th May 1921. It began suddenly in all the magnetic elements at 13 hours 8 minutes, Greenwich Mean Time, on the 13th May, and was practically simultaneous at all the magnetic observatories—to the degree of accuracy with which it is possible to measure time on the magnetograms. The main features of the disturbance correspond closely at all the observatories though they differ from each other in amplitude and period. In horizontal force and declination the largest perturbations are at Dehra Dūn and next in order of intensity are those at Toungoo and Kodaikānal. In the vertical force the intensity is about the same at Dehra Dūn and Kodaikānal and less at Toungoo. A prominent feature in the horizontal force at all the observatories is the speed and amplitude of the disturbance between 21 hours 20 minutes and 21 hours 41 minutes, G.M.T., on the 13th. This feature shows up to a much lesser extent in the other elements. Minor rapid fluctuations followed and the greatest activity in all the elements began on the 14th at 22 hours 15 minutes, G.M.T., and lasted for about 10 hours, during which time the movements in the horizontal force were so rapid that no record was obtained on the photographic paper in the downward movement, which was the greatest phase of the storm. After this there was a gradual rise in the horizontal force up to about 2 hours 20 minutes, G.M.T., on the 16th with frequent long and short period oscillations. Between 9 hours and 10 hours, G.M.T., a depression again occurred when the trace went beyond the limits of the magnetogram. A gradual rise with minor oscillations then continued up to 7 hours 48 minutes, G.M.T., on the 17th, when the storm ceased. The other elements showed no very marked variations after the ten hours of great disturbance on the 14th.

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It is noteworthy that this storm synchronized with the reported display of the Auroræ and with the appearance of large sun-spots which seem to be so closely associated with magnetic disturbances.

Programme for 1921-22.—During the ensuing field season observations will be taken for the comparison of instruments at the Dehra Dūn and Toungoo observatories. The Kodaikānal and Alībāg observatories, under the Meteorological Department, will also be visited for the same purpose.

Magnetic observations will be taken at six repeat stations—Quetta, Karāchi, Bīna, Dibrugarh, Barrackpore and Waltair—for the purpose of supplementing the 5-yearly observations at all the repeat stations, in order to obtain reliable values of the annual changes in the magnetic elements, as explained in the beginning of this report.

II.—The Observatories in 1920-21.

Dehra Dun Observatory.

1. The declination and horizontal force magnetographs have worked satisfactorily during the year. Some trouble was experienced with the vertical force instrument. It was adjusted on the 6th November on account of a shift in the magnet line on the magnetogram due to secular change. The adjustment, however, was not satisfactory, owing to the presence of insects which crawled about the magnet system and frequently agitated it. The adjustment was repeated on the 8th, but the sensitiveness of the instrument was disturbed and the scale value rose to nearly 12 gammas. On the 3rd December the instrument was adjusted again and the scale value reduced to 9 gammas.

Sulphuric acid was placed in a small cup inside the damping box and renewed every third day to destroy the insects, which were not exterminated until after the middle of December.

The clock of the vertical force instrument stopped on the 19th June owing to the works being clogged. In the attempt to clean it the observer had evidently disturbed the instrument and the magnet line appeared very low on the magnetogram: this was adjusted on the 29th June. The clock again stopped on the 5th July and continued to work unsatisfactorily until it was discovered on the 20th that the pin which connects it to the cut-off was at fault, this was set right on the 21st. Unfortunately, insects again disturbed the magnet system, which was removed and brushed, the agate supports cleaned and the system adjusted on the 28th. Insects continued to cause trouble and on the 19th August the magnet system was again removed and cleaned and the sensitiveness of the system re-adjusted when the scale value was brought down to 6 gammas. There were, however, still signs of insects and cleaning and adjustment were once more necessary on the 26th. On this occasion *formalin* was placed in the cup inside the damping box to destroy the insects and this appears so far to have had the desired effect.

The passage round the underground room of the observatory was flooded again this year. The inundation began early in the first week of September after heavy rain in the hills. The water first seen in the passage was 6 inches deep and on the third day, after continuous rain, rose to 3 feet and flowed over the barrier at the entrance to the inner room. The water was accumulating so fast that it was not possible to expel it quickly enough with the pump at the observatory and bailing out the water had to be resorted to as well. Coolies were employed day and night for two days pumping and bailing out the water, after which it decreased to 6 inches in the passage and three days later subsided on a cessation of rain in the hills. On the recurrence of heavy rain in the second week, water again entered the passage and there was additional leakage from fresh cracks in the walls of the passage. It was also noticed that the plastering which had bulged in the north wall some years previously had swelled out more. The water gradually rose to about 2 feet in spite of continuous bailing and pumping but subsided again after a few days at the end of the third week.

The walls of the observatory have suffered much, year after year, from the effects of the repeated pressure of the subsoil water and there is great risk of the observatory being badly flooded during future heavy rains and of the walls being considerably weakened. No means of improving the condition of the building seems feasible and the only solution, to avoid a disaster, is to build a new observatory above ground level.

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2. *Mean values of the declination and H. F. constants.*—The table below gives the mean monthly values of the magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$, and the accepted values of p and q used in determining the values of the distribution factor. The values of the moment "*m*" are also given, as determined by the revised distribution factor and moment of inertia used for the computations in 1915. The values of "*m*" in the table were derived from vibration observations taken with the chronograph.

Mean values of the constants of magnet No. 17 in 1920.

Months.	Declination constants.	H. F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
	′ ″						
January ...	− 7 0	6·02	7·16			806·73	806·73
February ...	− 7 6	6·11	6·64			806·73	806·73
March ...	− 7 1	6·11	6·45			806·66	806·66
April ...	− 7 3	6·02	6·64			806·53	806·53
May ...	− 7 7	6·07	6·70			806·50	806·50
June ...	− 7 5	6·00	6·68	7·30	−·382	806·40	806·40
July ...	− 7 3	6·01	6·48			806·34	
August ...	− 7 1	6·08	6·55			806·35	
September ...	− 7 5	6·03	6·41			806·32	
October ...	− 6 56	5·93	6·39			806·66	806·34
November ...	− 6 53	5·84	6·75			806·82	
December ...	− 6 50	5·99	6·59			806·91	

3. *Mean base line values.*—The table below gives the mean monthly observed and accepted values of the declination and horizontal force base lines: the accepted values have been used to compute the values of these elements for 1920. The H. F. base lines have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

Base line values of magnetographs in 1920.

Months.	Declination.			Horizontal Force.		
	Mean value of Base line.	Base line accepted.	Remarks.	Mean value of Base line.	Base line accepted.	Remarks.
	° ′	° ′		C. G. S.	C. G. S.	
January ...	1 3·8	1 3·8		·32689	·32689	
February ...	1 3·3	1 3·8		·32691	·32691	
March ...	1 3·7	1 3·7		·32692	·32692	
April ...	1 4·2	1 4·2		·32692	·32692	
May ...	1 4·4	1 4·4		·32690	·32690	
June ...	1 4·4	1 4·4		·32687	·32687	
July ...	1 4·3	1 4·3		·32682	·32682	
August ...	1 4·2	1 4·2		·32685	·32685	
September ..	1 4·3	1 4·3		·32686 ·32682 ·32677	·32686 ·32682 ·32677	To 18th. for 19th & 20th. From 21st to end.
October ...	1 3·9	1 3·9		·32671	·32671	
November ...	1 3·9	1 3·9		·32667 ·32663 ·32659	·32667 ·32663 ·32659	To 9th. for 10th. From 11th to end.
December ...	1 3·9	1 3·9		·32657	·32657	

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4. *Mean scale values and temperature range.*—The mean scale values for 1920 for an ordinate of 1/25 inch are :—

Horizontal Force	4·39 gammas, up to July.
	4·36 „ from August to December.
Declination	1·03 minutes.
Vertical Force	8·46 to 11·92 gammas.

The mean temperature for the year was 25°·7 C.; with maximum and minimum monthly values of 26°·3 C. and 25°·5 C. The temperature of reduction is 27°·0 C.

5. *Mean monthly values and annual changes.*—The following table shows the monthly mean values of the magnetic elements for 1919 and 1920 and the annual changes for that period. The annual changes in the horizontal force are deduced from the values of H corrected for the moment of inertia and the distribution factor used in the computations for 1915.

Annual changes at Dehra Dūn in 1919-20.

Months.	Horizontal Force ·32000 C. G. S. +			Declination E. 1°+			Dip N. 44° +			Vertical Force ·32000 C. G. S. +		
	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	956	966	+10	58·5	54·4	−4·1	53·0	57·6	+4·6	822	920	+ 98
February ...	960	967	+ 7	58·4	53·6	−4·8	52·6	57·9	+5·3	818	926	+108
March ...	957	956	− 1	58·1	53·6	−4·5	53·5	59·0	+5·5	831	936	+105
April ...	962	950	−12	57·2	53·1	−4·1	53·2	59·6	+6·4	832	943	+111
May ...	955	961	+ 6	56·7	52·7	−4·0	54·4	59·2	+4·8	848	945	+ 97
June ...	980	969	−11	56·0	52·2	−3·8	53·3	59·1	+5·8	851	951	+100
July ...	978	966	−12	55·5	51·8	−3·7	54 0	59·5	+5·5	862	955	+ 93
August ..	954	957	+ 3	55·2	51·3	−3·9	55·7	60·5	+4·8	872	965	+ 93
September ...	943	940	− 3	55·1	51·1	−4·0	56·4	61·3	+4·9	874	966	+ 92
October ...	951	929	−22	54·3	50·4	−3·9	57·7	61·8	+4·1	908	964	+ 56
November ...	975	924	−51	54·1	49·9	−4·2	56·9	61·8	+4·9	917	959	+ 42
December ..	967	926	−41	54·1	49·4	−4·7	57·4	61·8	+4·4	916	961	+ 45
Means ...	962	951	−11	56·1	52·0	−4·1	54·8	59·9	+5·1	863	949	+87

Toungoo Observatory.

1. The magnetographs have worked well during the year. The horizontal force and vertical force instruments were adjusted on the 28th February and 5th May respectively on account of the shift in the magnet line on the magnetograms, due to secular change and loss of magnetism.

Owing to a rapid rate of decrease in the moment of this observatory collimator magnet No. 19 A, as compared with the magnets of the other observatories, it was decided to replace it this year by the spare magnet No. 20 which was formerly in use at the Barrackpore observatory. Full sets of comparative observations of all the elements were made with No. 4 and No. 19A from the 14th to the 22nd February 1921 and with No. 4 and No. 20 from the 23rd Feb. to 3rd March, the vibration experiments in the horizontal force observations being taken both by the eye-and-ear method and by chronograph. Complete sets of observations to determine the moment of inertia of No. 19A and No. 20 were also taken.

Observations were made with both magnets 19A and 20 for a month after the above comparisons were taken and before No. 20 was finally substituted for No. 19A.

The galvanometer, used in connection with the Earth-Inductor, was working unsatisfactorily from the 10th May, from which date no dip observations were taken until a month later when the instrument was put in order. The hooks of the stirrup (at the lower end of the suspension) by which the galvanometer magnet is suspended became loose. The suspension had evidently been raised and was not lowered to its normal position when the arrester clips were used for arresting the magnet and consequently, instead of the disc above the stirrup being gripped, the clips must have come in contact with the hooks and loosened the solder by which they are attached to the cross-piece of the stirrup. After complete instructions had been sent to the observer for repairing the stirrup and adjusting the

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instrument he succeeded, after several attempts, in finally putting it into working order. Dip observations were then resumed on the 11th June.

The observer reported that on the 16th May the deflection scale in the magnetometer was not visible through the telescope and he placed a rubber band at one end of the deflection magnet to incline the mirror to enable him to see the scale. He was directed to remove the band and written instructions were sent to him for adjusting the mirror which he was able to effect on the 4th June. There was a slight improvement in P after this. On the 29th June the suspension fibre of the deflection magnet was changed and from that date the values of $P_{1.2}$ and $P_{2.3}$ were again unsatisfactory, no doubt due to a wrong height of suspension being used and presumably also to imperfect estimation of the vernier readings. After written advice was sent to the observer, who is a newly-trained hand, a marked improvement was noticed towards the end of August.

Chronometer No. 4464, which was in use for many years at this observatory and had always kept good time, suddenly went out of order on the 12th April. A spare chronometer, No. 6543, was used for a fortnight until another, No. 4762, was received from the Mathematical Instrument Office, Calcutta. No. 4464 was returned to store at Calcutta.

The canvas which covers the matting on the roof of the observatory has deteriorated and there was leakage in some parts of the building during the last rainy season. The Executive Engineer at Toungoo has proposed to renew the roof with *ruberoid*, which is more durable than the matting and canvas.

2. *Mean values of the Declination and H.F. constants.*—The table below gives the mean monthly values of the magnetic collimation, the distribution constants $P_{1.2}$ and $P_{2.3}$ and the accepted values of p and q used in determining the values of the distribution factor. The values of the moment "m" are also given, as determined with the revised distribution factor and moment of inertia used for the computations in 1915. The accepted values of "m" in the table were derived from vibration observations taken with the chronograph. There has been a drop in $P_{2.3}$ as well as in "m" from July, which seems to indicate a change in the latter constant: this will be examined when the final adjustment of the constants is taken up.

Mean values of the constants of magnet No. 19A in 1920.

Months.	Declination constants.	H. F. constants.						Remarks.
		Distribution Factors.				Mean values of m.		
	Mean magnetic collimation.	$P_{1.2}$	$P_{2.3}$	Accepted values p	Accepted values q	Monthly means.	Accepted m.	
	′ ″							
January ...	− 11 6	8·17	9·46			865·58		
February ...	− 11 9	8·11	9·62			865·59	865·43	to 15th April.
March ...	− 11 7	8·12	9·31			865·56		
April ...	− 11 8	8·10	9·33			865·56 865·28	865·10	from 17th April to the end.
May ...	− 11 10	8·20	9·50			865·23 864·82	865·00	
June ...	− 11 25	8·21	9·55	10·19	−·546	864·81	864·96	
July ...	− 11 20	8·31	9·30			864·77 864·56	864·77	to 21st July.
August ...	− 11 17	8·31	8·45			864·66		
September ...	− 11 11	8·24	8·39			864·60		
October ...	− 11 32	8·28	8·41			864·43	864·59	from 22nd July.
November ...	− 11 29	8·24	8·35			864·68		
December ...	− 11 36	8·29	8·15			864·61		

3. *Mean base line values.*—The table below gives the mean monthly observed and accepted values of the declination and horizontal force base lines: the accepted values have been used to compute the values of these elements for 1920. The H.F. base line values have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

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Base line values of magnetographs in 1920.

Months.	Declination.		Horizontal Force.	
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.
	° ′	° ′	C. G. S.	C. G. S.
January	1 15·0	1 15·6	·38664	·38664
February	1 15·0	1 15·0	·38669	·38669
March	1 15·0	1 15·0	·38676	·38668
April	1 14·9	1 14·9	·38672	·38666
May	1 15·2	1 15·2	·38662	·38662
June	1 14·9	1 14·9	·38661	·38661
July	1 14·9	1 14·9	·38647	·38647
August	1 14·9	1 14·9	·38640	·38640
September	1 15·2	1 15·2	·38641	·38641
October	1 15·0	1 15·0	·38642	·38642
November	1 14·9	1 14·9	·38648	·38648
December	1 15·0	1 15·0	·38651	·38651

4. *Mean scale values and temperature range.*—The mean scale values for 1920 for an ordinate of 1/25 inch are:—

Horizontal Force	5·36 gammas.
Declination	1·04 minutes.
Vertical Force	5·71 gammas, up to June.
	5·74 „ from July to December.

The mean temperature for the year was 89°·1 Fahr. with maximum and minimum values of 89°·5 Fahr. and 89°·0 Fahr. The temperature of reduction is 89°·0 Fahr.

5. *Mean monthly values and annual changes.*—The table below shows the monthly mean values of the magnetic elements for 1919 and 1920 and the annual changes for that period. The annual changes in the horizontal force are deduced from the values of H corrected for the moment of inertia and the distribution factor used in the computations for 1915.

Annual changes at Toungoo in 1919-20.

Months.	Horizontal Force ·39000 C. G. S. +			Declination W 0°+			Dip N. 23°+			Vertical Force ·16000 C. G. S. +		
	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	81	106	+25	19·0	22·3	+3·3	8·5	7·7	−0·8	703	703	0
February ...	90	113	+23	18·9	22·6	+3·7	8·1	7·8	−0·3	701	708	+ 7
March ...	71	107	+36	19·1	22·7	+3·6	8·3	7·7	−0·6	696	703	+ 7
April ...	89	105	+16	19·6	23·0	+3·4	8·4	8·2	−0·2	705	710	+ 5
May ...	86	114	+28	19·9	23·5	+3·6	8·6	7·7	−0·9	706	707	+ 1
June ...	116	128	+12	19·8	23·4	+3·6	7·5	7·7	+0·2	705	712	+ 7
July ...	118	118	0	20·1	23·6	+3·5	7·8	7·8	0·0	709	710	+ 1
August ...	94	109	+15	20·5	23·9	+3·4	8·9	7·9	−1·0	713	706	− 7
September ...	91	103	+12	21·1	24·5	+3·4	8·7	7·9	−0·8	709	705	− 4
October ...	96	110	+14	21·3	24·7	+3·4	8·8	7·7	−1·1	714	704	−10
November ...	116	121	+ 5	21·5	24·8	+3·3	8·0	7·5	−0·5	711	707	− 4
December ...	118	133	+15	22·0	25·3	+3·3	8·0	7·3	−0·7	712	709	− 3
Means ...	97	114	+17	20·2	23·7	+3·5	8·3	7·7	−0·6	707	707	0

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Kodaikanal Observatory.

1. This observatory is under the control of the Meteorological Department, but the absolute observations and the records of the self-registering instruments are forwarded periodically by the Director of the observatory for computation and for record in the party.

The working of the magnetographs has not been entirely satisfactory. The clock which works the drums of both the declination and horizontal force magnetographs stopped on several occasions during the year—on the 1st and 2nd October, 28th October, 14th February, 27th June and 3rd July. The first and last stoppages were due to the snapping of the chord which supports the weight of the clock. The cause of the stoppages for the intervening dates is not stated.

The base line traces in the declination magnetograms were sometimes very faint in the month of January but after the end of the month there was some improvement.

From the middle of May to the end of June the base line traces in the vertical force magnetograms were also very often faint. It is stated that the magnet was not moving freely and adjustments were made. On the 5th July the axis of the drum of the vertical force instrument was made vertical. From the 16th to the 19th August the vertical force instrument was opened for cleaning as insects had got in.

2. *Mean values of the Declination and H.F. constants.*—The table below gives the mean monthly values of the magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$ and the accepted values of p and q used in determining the values of the distribution factor. The values of the moment "m" are also given, as determined by the revised distribution factor and moment of inertia used for the computations in 1915. The values of "m" in the table were derived from vibration observations taken with the chronograph.

Mean values of the constants of magnet No. 16 in 1920.

Months.	Declination constants.	H.F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
	′ ″						
January ...	− 3 24	6·45	8·27			882·21	
February ...	− 3 24	6·50	8·07			882·20	
March ...	− 3 20	6·51	7·90			882·12	
April ...	− 3 20	6·47	8·08			882·14	
May ...	− 3 16	6·45	8·18			...	
June ...	− 3 19	6·56	8·27	11·39	−1621	882·19	881·74 throughout
July ...	− 3 16	6·45	8·10			882·17	
August ...	− 3 19	6·46	8·18			882·11	
September ...	− 3 19	6·45	7·93			882·10	
October ...	− 3 21	6·49	7·98			882·15	
November ...	− 3 15	6·56	8·43			882·09	
December ...	− 3 18	6·51	8·17			882·27	

3. *Mean base line values.*—The table below gives the mean monthly observed and accepted base line values of the declination and horizontal force magnetographs: the accepted values have been used to compute the values of these elements for 1920. The horizontal force base line values have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

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Base line values of magnetographs in 1920.

Months.	Declination.			Horizontal Force.	
	Mean value of Base line.	Base line accepted	Remarks.	Mean value of Base line.	Base line accepted
	° ′	° ′		C. G. S.	C. G. S.
January ...	3 9·2	3 9·2		·37347	.37347
February ...	3 9·5	3 9·5		·37348	·37348
March ...	3 9·5	3 9·5		·37348	·37348
April ...	3 9·5	3 9·5		·37350	·37350
May ...	3 9·5	3 9·5		·37344	·37344
June ...	3 9·6	3 9·6	To 10h. on 21st.	·37348	·37348
"	2 58·3	2 58·3	From 9h. on 22nd.		
July ...	2 58·4	2 58·4	To 18th.	·37353	·37353
" ...	2 57·5	2 57·5	From 19th.		
August ...	2 57·8	2 57·8		·37358	·37358
September ...	2 58·2	2 58·2		·37353	·37353
October ...	2 58·4	2 58·4		·37348	·37348
November ...	2 58·3	2 58·3		·37346	·37346
December ...	2 58·1	2 58·1		·37346	·37346

4. *Mean scale values and temperature range.*—The mean scale values for 1920 for an ordinate of 1/25 inch are :—

Horizontal Force 5·93 gammas, up to July.
5·91 „ from August to December.
Declination 1·03 minutes.
Vertical Force 7·17 to 8·06 gammas.

The mean temperature for the year was 17°·1 C.; with maximum and minimum values of 18°·0 C. and 16°·0 C. The temperature of reduction is 19°·0 C.

5. *Mean monthly values and annual changes.*—The table below gives the monthly mean values of the magnetic elements for 1919 and 1920 and the annual changes for that period. The annual changes in the horizontal force are deduced from the values of H corrected for the moment of inertia and the distribution factor used in the computations for 1915.

Annual changes at Kodaikānal in 1919-20.

Months.	Horizontal Force ·37000 C. G. S.+			Declination W. 1° +			Dip N. 4° +			Vertical Force ·02000 C. G. S.+		
	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.	1919.	1920.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	732	775	+ 43	41·7	47·5	+ 5·8	31·5	34·4	+ 2·9	986	1021	+ 35
February ...	739	779	+ 40	42·2	47·9	+ 5·7	31·8	34·7	+ 2·9	989	1025	+ 36
March ...	735	767	+ 32	42·8	48·0	+ 5·2	32·1	35·6	+ 3·5	993	1034	+ 41
April ...	749	765	+ 16	43·5	48·6	+ 5·1	32·7	36·2	+ 3·5	1000	1040	+ 40
May ...	744	777	+ 33	43·7	49·0	+ 5 3	32·9	36·6	+ 3 7	1002	1046	+ 44
June ...	766	791	+ 25	44·3	49·8	+ 5·5	33·5	36·1	+ 2·6	1011	1042	+ 31
July ...	706	794	+ 28	44·1	50·6	+ 6·5	34·2	36·3	+ 2·1	1018	1044	+ 26
August ...	749	795	+ 46	44·8	51·0	+ 6·2	35·5	36·7	+ 1·2	1031	1049	+ 18
September ...	752	792	+ 40	46·2	51·0	+ 4·8	33·8	36·4	+ 2·6	1013	1045	+ 32
October ...	759	798	+ 39	46·4	51·5	+ 5·1	34·4	36·7	+ 2·3	1020	1049	+ 29
November ...	774	799	+ 25	46·7	51·9	+ 5·2	34·7	36·8	+ 2·1	1025	1050	+ 25
December ...	772	806	+ 34	47·4	52·3	+ 4·9	35·1	37·1	+ 2·0	1029	1054	+ 25
Means ...	753	787	+ 33	44·5	49·9	+ 5·4	33·5	36·1	+ 2·6	1010	1042	+ 32

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III.—Table of Results.

Mean values of the magnetic elements at observatories in 1920.

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
	° ′ ″	° ′	° ′	C. G. S.	C. G. S.
Dehra Dūn ...	30 19 19 N. 78 3 19 E.	N. 44 59·9	E. 1 52·0	·32951	·32949
Toungoo ...	18 55 45 N. 96 27 3 E.	N. 23 7·7	W. 0 23·7	·39114	·16707
Kodaikānal ...	10 13 50 N. 77 27 46 E.	N. 4 36·1	W. 1 49·9	·37787	·03042

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D = Dehra Dūn ... { Lat. 30 ° 19 ′ 19 ″ N. Long. 78 3 19 E.

T = Toungoo ... { Lat. 18 55 45 N. Long. 96 27 3 E.

K = Kodaikānal ... { Lat. 10 ° 13 ′ 50 ″ N. Long. 77 27 46 E.

Classification and dates of Magnetic disturbances in 1920.

1920	January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
Dates.	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K
1 ...	S	S	S	C	C	C	C	C	C	C	C	C	M	M	M	S	S	C	S	S	S	C	C	C	S	S	S	M	—	—	S	S	S	C	C	C
2 ...	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	C	C	C	C	C	C	C	M	S	S	—	—	S	S	S	S	S	S
3 ...	S	S	S	C	C	C	C	C	S	C	C	C	S	S	S	C	C	S	C	C	C	S	S	S	M	S	S	S	S	—	S	S	S	M	M	M
4 ...	C	C	C	C	C	C	S	S	S	M	M	S	S	C	S	S	S	S	C	C	C	S	S	S	M	M	S	S	S	S	S	S	S	M	M	M
5 ...	C	C	C	C	C	C	G	G	G	M	M	S	S	C	C	S	S	S	C	C	C	S	S	S	S	S	C	S	S	S	S	S	S	M	M	M
6 ...	C	C	C	C	C	C	S	S	S	S	S	S	C	C	C	S	S	C	C	S	S	S	C	S	C	C	S	C	C	S	S	S	S	M	M	M
7 ...	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	C	S	S	S	S	S	S	C	S	S	S	S	S	S	S	S	S	S
8 ...	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	C	S	S	S	S	S	M	S	S	S	S	S	C	C	C	S	S	S
9 ...	S	S	S	C	C	C	C	C	C	S	S	C	M	C	M	C	C	C	C	S	S	S	C	S	S	S	S	S	S	S	C	M	S	S	S	S
10 ...	S	S	S	C	C	C	S	S	S	S	C	C	C	C	C	M	M	C	C	S	S	S	S	S	S	S	S	S	C	S	S	C	C	C	C	C
11 ...	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C	S	S	C	S	S	S	C	S	S	S	S	S	C	S	S	C	C	C	C	C	C
12 ..	S	S	S	S	S	S	S	S	S	C	C	C	C	G	C	S	S	C	S	S	S	M	S	M	S	S	C	C	C	C	S	C	C	C	C	C
13 ...	C	C	S	S	S	S	S	G	S	C	C	C	G	M	C	S	C	C	S	S	S	S	C	S	S	S	S	S	S	S	C	C	C	S	S	S
14 ...	S	S	S	S	S	S	G	G	G	C	G	C	M	M	M	C	C	C	S	M	S	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S
15 ...	S	S	S	S	S	S	M	M	M	G	G	G	M	S	S	S	S	—	M	S	M	S	C	C	S	S	S	S	S	S	C	C	C	S	S	S
16 ...	S	S	S	M	M	M	S	S	S	S	S	S	S	S	S	S	S	C	S	S	S	C	C	C	S	S	S	S	S	S	C	C	C	S	S	S
17 ...	C	C	C	M	M	M	S	S	S	S	S	S	S	S	C	S	C	C	S	S	S	C	S	S	C	C	C	S	S	S	C	C	C	S	S	S
18 ...	C	C	C	S	S	S	C	C	C	S	S	C	C	C	C	C	C	S	S	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S
19 ...	C	C	C	C	C	C	C	C	C	S	—	C	C	C	S	S	S	S	—	C	C	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S
20 ...	C	C	C	C	C	C	C	C	C	S	S	S	C	C	S	S	S	S	C	S	S	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S
21 ...	S	S	S	S	S	S	S	S	S	S	S	C	S	S	C	S	S	—	C	S	C	C	C	C	S	S	S	S	S	S	C	C	C	S	S	S
22 ...	C	C	C	C	C	C	V.G.	V.G.	V.G.	C	C	C	S	C	C	S	S	—	S	S	S	S	S	S	M	M	S	C	C	C	S	S	S	S	S	S
23 ...	S	S	S	C	C	C	V.G.	V.G.	V.G.	C	C	C	S	C	C	S	S	C	S	S	S	S	S	S	M	M	S	C	C	C	S	S	S	C	C	C
24 ...	S	S	S	M	M	M	M	M	M	C	S	S	S	C	C	S	S	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C
25 ...	C	C	S	S	S	S	M	M	M	C	C	C	S	S	S	S	S	C	S	C	S	C	C	C	S	S	S	C	C	C	M	M	M	M	M	M
26 ...	S	S	S	S	S	S	M	M	M	C	C	C	S	S	S	C	C	C	S	C	S	C	C	C	S	S	S	C	C	C	S	S	S	M	M	M
27 ...	C	C	C	S	S	S	S	S	S	C	C	C	M	M	S	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	M	M	M	S	S	S
28 ...	S	S	S	S	S	S	S	S	S	C	C	C	M	M	M	S	S	S	C	C	C	C	C	C	G	G	M	S	S	S	C	C	C	S	S	S
29 ...	S	S	S	C	C	C	C	C	C	C	C	C	M	M	S	S	S	S	C	C	C	C	C	C	S	G	S	S	S	C	C	C	C	C	C	C
30 ...	S	S	S	...	...	...	C	C	C	S	S	S	S	C	S	S	S	S	C	C	C	S	C	C	...	...	...	C	C	C	...	...	...	C	C	S
31 ...	S	S	S	...	...	...	C	C	C	...	..	...	C	C	C	...	...	...	C	C	C	S	C	C	...	...	...	C	C	—	...	...	...	S	S	S
C ...	11	11	11	13	13	13	10	10	10	15	16	17	12	12	14	11	12	14	12	13	12	11	12	13	8	8	9	10	10	9	13	13	13	9	9	9
S ...	20	20	20	13	13	13	13	13	13	12	10	12	11	12	12	18	17	11	16	17	18	18	17	17	16	16	15	18	18	14	15	15	15	17	17	17
M ...	...	...	...	3	3	3	4	4	4	2	2	...	7	6	4	1	1	1	1	1	1	2	2	1	4	5	5	3	3	1	2	2	2	5	5	5
G ...	...	...	.	...	...	...	2	2	2	1	1	1	1	1	1	...	...	...	...	...	...	...	...	...	2	1	1	...	...	...	...	...	...	...	..	...
V.G. ...	...	...	...	...	...	...	2	2	2	..	...	..	...	...	...	...	...	4	2	...	...	...	...	...	...	...	...	...	...	7	...	...	...	...	...	...
Trace lost ...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...		...	...	...	...	...	...

C = Calm. S = Slight. M = Moderate. G = Great. V.G. = Very Great. — = Trace lost.

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Hourly Means of the Declination at Dehra Dun in 1920, determined from all available days. Declination = E. 1° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter	Jan.	54·8	54·8	54·6	54·6	54·3	53·8	53·7	53·6	54·4	55·6	**55·9**	54·8	53·6	**53·3**	53·3	53·6	54·0	54·5	54·7	54·7	54·7	54·9	54·8	54·9	54·8	54·4
	Feb.	54·3	54·1	54·0	53·6	53·4	53·0	52·8	52·8	53·8	55·1	**55·7**	55·3	54·3	53·1	52·5	**52·3**	52·5	53·1	53·3	53·5	53·6	53·6	53·7	53·9	54·0	53·6
	Mar.	53·8	53·8	53·8	53·7	53·4	53·3	53·6	54·2	55·6	**56·1**	55·2	53·8	52·4	**51·5**	51·6	52·4	53·3	53·6	53·3	53·2	53·2	53·4	53·6	**53·8**	53·8	53·6
	Oct.	50·8	50·9	50·8	50·5	50·4	50·3	50·3	51·0	**51·8**	51·7	50·8	49·6	48·5	**48·5**	49·2	50·1	50·5	50·4	50·3	50·3	50·4	50·5	50·5	**50·6**	50·6	50·4
	Nov.	50·2	50·0	49·9	49·8	49·7	49·6	49·6	49·9	**50·6**	50·5	49·8	48·8	**48·6**	49·1	49·7	50·2	50·1	49·9	49·9	50·2	50·0	50·3	50·3	**50·3**	50·1	49·9
	Dec.	49·5	49·6	49·2	49·1	48·8	**48·8**	48·9	49·1	50·0	**50·4**	49·7	48·4	**48·2**	48·7	49·4	50·0	49·9	49·7	49·8	49·8	49·8	49·6	49·5	**49·5**	49·4	49·4
	Means	52·2	52·2	52·1	51·9	**51·7**	51·5	51·5	51·8	52·7	**53·2**	52·9	51·8	50·9	**50·7**	51·0	**51·4**	51·7	51·9	51·9	52·0	52·0	52·1	52·1	**52·2**	52·1	51·9
Summer	April	53·5	53·7	53·7	53·8	53·6	53·5	53·9	54·9	**55·9**	55·7	54·0	52·1	50·7	**50·2**	50·5	51·5	52·3	52·9	53·0	52·9	52·9	53·0	53·1	**53·1**	53·8	53·1
	May	53·1	53·2	53·3	53·2	53·3	53·7	54·9	55·7	**55·9**	54·8	52·9	51·1	49·9	**49·7**	50·3	51·3	52·1	52·7	52·7	52·3	52·1	52·2	52·5	**52·7**	53·0	52·7
	June	52·4	52·7	52·8	52·8	52·9	53·2	54·6	55·7	**55·7**	55·0	53·3	51·1	49·4	**48·7**	48·8	49·4	50·3	51·4	52·0	51·8	51·7	51·8	52·0	**52·2**	52·4	52·2
	July	52·0	52·3	52·4	52·4	52·6	52·9	54·3	**55·3**	55·1	53·9	52·1	50·1	49·0	**48·8**	48·9	49·5	50·4	51·2	51·7	51·4	51·2	51·3	51·6	**51·8**	51·9	51·8
	Aug.	51·5	51·7	51·8	51·9	52·0	52·4	53·9	**54·9**	54·8	53·4	51·1	49·1	48·1	**47·8**	48·3	49·3	50·4	51·0	51·3	51·0	51·0	51·0	51·2	**51·3**	51·5	51·3
	Sep.	51·4	51·6	51·7	51·6	51·6	51·8	52·4	53·5	**54·1**	53·1	51·2	49·2	48·2	**48·1**	48·7	49·8	51·1	51·5	51·2	51·1	51·0	51·2	51·2	**51·1**	51·3	51·1
	Means	52·3	52·5	52·6	52·6	52·7	52·9	54·0	55·0	**55·3**	54·3	52·4	50·5	49·2	**48·9**	49·3	50·1	51·1	51·8	52·0	51·8	51·7	51·8	51·9	**52·0**	52·2	52·0

Diurnal Inequality of the Declination at Dehra Dun in 1920, deduced from the above table.

Winter	Jan.	+0′4	+0′4	+0′2	+0′2	−0′1	−0′6	−0′7	−0′8	0′0	+1′2	+1′5	+0′4	−0′8	−1′1	−1′1	−0′8	−0′4	+0′1	+0′3	+0′3	+0′3	+0′5	+0′4	+0′5	+0′4	
	Feb.	+0·7	+0·5	+0·4	0·0	−0·2	−0·6	−0·8	−0·8	+0·2	+1·5	+2·1	+1·7	+0·7	−0·5	−1·1	−1·3	−1·1	−0·5	−0·3	−0·1	0·0	0·0	+0·1	+0·3	+0·4	
	Mar.	+0·2	+0·2	+0·2	+0·1	−0·2	−0·3	0·0	+0·6	+2·0	+2·5	+1·6	+0·2	−1·2	−2·1	−2·0	−1·2	−0·3	0·0	−0·3	−0·4	−0·4	−0·2	0·0	+0·2	+0·2	
	Oct.	+0·4	+0·5	+0·4	+0·1	0·0	−0·1	−0·1	+0·6	+1·4	+1·3	+0·4	−0·8	−1·9	−1·9	−1·2	−0·3	+0·1	0·0	−0·1	−0·1	0·0	+0·1	+0·1	+0·2	+0·2	
	Nov.	+0·3	+0·1	0·0	−0·1	−0·2	−0·3	−0·3	0·0	+0·7	+0·6	−0·1	−1·1	−1·3	−0·8	−0·2	+0·3	+0·2	0·0	0·0	+0·3	+0·1	+0·4	+0·4	+0·4	+0·2	
	Dec.	+0·1	+0·2	−0·2	−0·3	−0·6	−0·6	−0·5	−0·3	+0·6	+1·0	+0·3	−1·0	−1·2	−0·7	0·0	+0·6	+0·5	+0·3	+0·4	+0·4	+0·4	+0·2	+0·1	+0·1	0·0	
	Means	+0·3	+0·3	+0·2	0·0	−0·2	−0·4	−0·4	−0·1	+0·8	+1·3	+1·0	−0·1	−1·0	−1·2	−0·9	−0·5	−0·2	0·0	0·0	+0·1	+0·1	+0·2	+0·2	+0·3	+0·2	
Summer	April	+0·4	+0·6	+0·6	+0·7	+0·5	+0·4	+0·8	+1·8	+2·8	+2·6	+0·9	−1·0	−2·4	−2·9	−2·6	−1·6	−0·8	−0·2	−0·1	−0·2	−0·2	−0·1	0·0	0·0	+0·2	
	May	+0·4	+0·5	+0·6	+0·5	+0·6	+1·0	+2·2	+3·0	+3·2	+2·1	+0·2	−1·6	−2·8	−3·0	−2·4	−1·4	−0·6	0·0	0·0	−0·4	−0·6	−0·5	−0·2	0·0	+0·3	
	June	+0·2	+0·5	+0·6	+0·6	+0·7	+1·0	+2·4	+3·5	+3·5	+2·8	+1·1	−1·1	−2·8	−3·5	−3·4	−2·8	−1·9	−0·8	−0·2	−0·4	−0·5	−0·4	−0·2	0·0	+0·2	
	July	+0·2	+0·5	+0·6	+0·6	+0·8	+1·1	+2·5	+3·5	+3·3	+2·1	+0·3	−1·7	−2·8	−3·0	−2·9	−2·3	−1·4	−0·6	−0·1	−0·4	−0·6	−0·5	−0·2	0·0	+0·1	
	Aug.	+0·2	+0·4	+0·5	+0·6	+0·7	+1·1	+2·6	+3·6	+3·5	+2·1	−0·2	−2·2	−3·2	−3·5	−3·0	−2·0	−0·9	−0·3	0·0	−0·3	−0·3	−0·3	−0·1	0·0	+0·2	
	Sep.	+0·3	+0·5	+0·6	+0·5	+0·5	+0·7	+1·3	+2·4	+3·0	+2·0	+0·1	−1·9	−2·9	−3·0	−2·4	−1·3	0·0	+0·4	+0·1	0·0	−0·1	+0·1	+0·1	0·0	+0·2	
	Means	+0·3	+0·5	+0·6	+0·6	+0·7	+0·9	+2·0	+3·0	+3·3	+2·3	+0·4	−1·5	−2·8	−3·1	−2·7	−1·9	−0·9	−0·2	0·0	−0·2	−0·3	−0·2	−0·1	0·0	+0·2	

NOTE.—When the sign is + the magnet points to the east, and when − to the west of the mean position.

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Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Dehra Dun in 1920, from all available days. Horizontal Force = ·32000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter	Jan.	γ 961	γ 963	γ 965	γ 964	γ 963	γ 967	γ 970	γ 972	γ **977**	γ 976	γ 972	γ 969	γ 971	γ 971	γ 971	γ 968	γ 966	γ 963	γ 960	γ 962	γ 961	γ **958**	γ 960	γ 961	γ 961	γ 966
	Feb.	**958**	960	960	960	961	964	968	971	977	981	**982**	980	977	973	969	966	966	**963**	964	961	961	961	961	961	960	967
	Mar.	946	949	946	**944**	945	949	951	953	954	960	968	976	**978**	976	970	964	958	955	953	950	950	950	946	948	**947**	956
	Oct.	925	925	926	929	930	932	932	930	930	930	932	935	942	**944**	940	932	927	**920**	922	920	921	925	928	928	930	929
	Nov.	920	922	924	925	925	927	928	929	929	928	929	933	**936**	936	931	924	921	918	917	917	915	**914**	916	915	921	924
	Dec.	919	918	922	924	927	929	930	931	931	929	926	934	**938**	938	935	931	927	921	918	916	**916**	918	920	918	920	926
	Means	938	940	941	941	942	945	947	948	950	951	952	955	**957**	956	953	948	944	940	939	938	**937**	938	939	939	940	945
Summer	April	944	947	949	948	948	950	950	945	**940**	943	951	961	969	**973**	967	958	951	945	943	943	944	946	947	948	**948**	950
	May	958	960	960	960	960	961	960	957	953	955	963	972	977	**978**	974	967	958	954	**952**	954	956	958	958	961	960	961
	June	967	965	965	966	966	968	970	968	963	**962**	967	970	977	**980**	980	977	973	967	963	961	965	967	968	968	967	969
	July	963	964	964	962	962	962	965	962	962	964	960	976	979	**981**	979	975	968	960	**956**	958	959	962	962	962	962	966
	Aug.	957	958	956	956	957	955	956	952	947	**945**	951	960	966	**969**	968	966	959	955	953	953	953	954	956	958	959	957
	Sep.	940	943	943	944	944	943	940	934	927	**926**	929	936	946	952	**957**	954	944	938	936	935	935	939	940	**942**	943	940
	Means	955	956	956	956	956	957	957	953	**949**	949	955	963	969	**972**	971	966	959	953	951	951	952	954	955	957	957	957

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1920, deduced from the above table.

Winter	Jan.	γ − 5	γ − 3	γ − 1	γ − 2	γ − 3	γ + 1	γ + 4	γ + 6	γ +11	γ +10	γ + 6	γ + 3	γ + 5	γ + 5	γ + 5	γ + 2	γ 0	γ − 3	γ − 6	γ − 4	γ − 5	γ − 8	γ − 6	γ − 5	γ − 5	
	Feb.	− 9	− 7	− 7	− 7	− 6	− 3	+ 1	+ 4	+10	+14	+15	+13	+10	+ 6	+ 2	− 1	− 1	− 4	− 3	− 6	− 6	− 6	− 6	− 6	− 7	
	Mar.	−10	− 7	−10	−12	−11	− 7	− 5	− 3	− 2	+ 4	+12	+20	+22	+20	+14	+ 8	+ 2	− 1	− 3	− 6	− 6	− 6	−10	− 8	− 9	
	Oct.	− 4	− 4	− 3	0	+ 1	+ 3	+ 3	+ 1	+ 1	+ 1	+ 3	+ 6	+13	+15	+11	+ 3	− 2	− 9	− 7	− 9	− 8	− 4	− 1	− 1	+ 1	
	Nov.	− 4	− 2	0	+ 1	+ 1	+ 3	+ 4	+ 5	+ 5	+ 4	+ 5	+ 9	+12	+12	+ 7	0	− 3	− 6	− 7	− 7	− 9	−10	− 8	− 9	− 3	
	Dec.	− 7	− 8	− 4	− 2	+ 1	+ 3	+ 4	+ 5	+ 5	+ 3	0	+ 8	+12	+12	+ 9	+ 5	+ 1	− 5	− 8	−10	−10	− 8	− ·	− 8	− 6	
	Means	− 7	− 5	− 4	− 4	− 3	0	+ 2	+ 3	+ 5	+ 6	+ 7	+10	+12	+11	+ 8	+ 3	− 1	− 5	− 6	− 7	− 8	− 7	− 6	− 6	− 5	
Summer	April	− 6	− 3	− 1	− 2	− 2	0	0	− 5	−10	− 7	+ 1	+11	+19	+23	+17	+ 8	+ 1	− 5	− 7	− 7	− 6	− 4	− 3	− 2	− 2	
	May	− 3	− 1	− 1	− 1	− 1	0	− 1	− 4	− 8	− 6	+ 2	+11	+16	+17	+13	+ 6	− 3	− 7	− 9	− 7	− 5	− 3	− 3	0	− 1	
	June	− 2	− 4	− 4	− 3	− 3	− 1	+ 1	− 1	− 6	− 7	− 2	+ 1	+ 8	+11	+11	+ 8	+ 4	− 2	− 6	− 5	− 4	− 2	− 1	− 1	− 2	
	July	− 3	− 2	− 2	− 4	− 4	− 4	− 1	− 4	− 4	− 2	+ 3	+10	+13	+15	+13	+ 9	+ 2	− 6	−10	− 8	− 7	− 4	− 4	− 4	− 4	
	Aug.	0	+ 1	− 1	− 1	0	− 2	− 1	− 5	−10	−12	− 6	+ 3	+ 9	+12	+11	+ 9	+ 2	− 2	− 4	− 4	− 4	− 3	− 1	+ 1	+ 2	
	Sep.	0	+ 3	+ 3	+ 4	+ 4	+ 3	0	− 6	−13	−14	−11	− 4	+ 6	+12	+17	+14	+ 4	− 2	− 4	− 5	− 5	− 1	0	+ 2	+ 3		
	Means	− 2	− 1	− 1	− 1	− 1	0	0	− 4	− 8	− 8	− 2	+ 6	+12	+15	+14	+ 9	+ 2	− 4	− 6	− 6	− 5	− 3	− 2	0	0	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

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Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Dehra Dun in 1920, from all available days. Vertical Force = ·32000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter Jan.	923	924	923	922	922	923	923	922	925	925	920	908	909	911	913	915	918	920	921	922	922	923	924	924	924	920
Winter Feb.	931	931	930	930	929	930	929	930	933	932	926	918	912	912	915	917	921	924	927	927	929	930	930	930	930	926
Winter Mar.	943	942	941	941	941	941	942	944	943	938	930	921	918	921	927	932	935	936	936	937	939	940	940	942	942	936
Winter Oct.	968	968	968	968	968	968	967	970	970	967	961	950	949	952	956	959	962	962	964	965	967	968	968	968	967	964
Winter Nov.	961	961	961	960	960	960	958	960	960	956	951	950	954	958	958	959	960	960	962	961	962	962	963	962	962	959
Winter Dec.	961	962	962	961	961	961	960	963	964	960	955	952	958	960	961	961	962	961	962	963	962	962	962	961	962	961
Means	948	948	948	947	947	947	947	948	949	946	941	933	933	936	938	941	943	944	945	946	947	948	948	948	948	944
Summer April	948	949	948	947	947	947	948	949	946	939	931	926	926	929	934	939	942	944	944	945	947	948	949	949	949	943
Summer May	952	952	952	951	951	952	955	953	946	938	932	927	930	936	941	945	947	949	949	949	951	952	952	953	953	945
Summer June	956	956	957	956	957	958	961	959	953	946	938	929	931	936	942	947	952	955	955	955	956	958	958	958	957	951
Summer July	960	960	960	960	961	962	966	963	957	950	941	935	938	942	945	950	955	958	959	959	960	962	962	962	962	955
Summer Aug.	969	970	970	970	970	971	974	972	966	958	952	949	951	954	959	964	966	967	968	968	970	971	972	971	971	965
Summer Sep.	969	970	969	970	969	969	970	971	969	964	956	950	951	955	961	965	966	967	966	967	969	969	970	971	970	966
Means	959	960	959	959	959	960	962	961	956	949	942	936	938	942	947	952	955	957	957	957	959	960	961	961	960	954

Diurnal Inequality of the Vertical Force at Dehra Dun in 1920, deduced from the above table.

	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter Jan.	+ 3	+ 4	+ 3	+ 2	+ 2	+ 2	+ 3	+ 2	+ 5	+ 5	0	−12	−11	− 9	− 7	− 5	− 2	0	+ 1	+ 2	+ 2	+ 3	+ 4	+ 4	+ 4	+ 4
Winter Feb.	+ 5	+ 5	+ 4	+ 4	+ 3	+ 4	+ 3	+ 4	+ 7	+ 6	0	− 8	−14	−14	−11	− 9	− 5	− 2	+ 1	+ 1	+ 3	+ 4	+ 4	+ 4	+ 4	+ 4
Winter Mar.	+ 7	+ 6	+ 5	+ 5	+ 5	+ 5	+ 6	+ 8	+ 7	+ 2	− 6	−15	−18	−15	− 9	− 4	− 1	0	0	+ 1	+ 3	+ 4	+ 4	+ 6	+ 6	+ 6
Winter Oct.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 3	+ 6	+ 6	+ 3	− 3	−14	−15	−12	− 8	− 5	− 2	− 2	0	+ 1	+ 3	+ 4	+ 4	+ 4	+ 3	+ 3
Winter Nov.	+ 2	+ 2	+ 2	+ 1	+ 1	+ 1	− 1	+ 1	+ 1	− 3	− 8	− 9	− 5	− 1	− 1	0	+ 1	+ 1	+ 3	+ 2	+ 3	+ 3	+ 4	+ 3	+ 3	+ 3
Winter Dec.	0	+ 1	+ 1	0	0	0	− 1	+ 2	+ 3	− 1	− 6	− 9	− 3	− 1	0	0	+ 1	0	+ 1	+ 2	+ 1	+ 1	+ 1	0	+ 1	+ 1
Means	+ 4	+ 4	+ 4	+ 3	+ 3	+ 3	+ 3	+ 4	+ 5	+ 2	− 3	−11	−11	− 8	− 6	− 3	− 1	0	+ 1	+ 2	+ 3	+ 4	+ 4	+ 4	+ 4	+ 4
Summer April	+ 5	+ 6	+ 5	+ 4	+ 4	+ 4	+ 5	+ 6	+ 3	− 4	−12	−17	−17	−14	− 9	− 4	− 1	+ 1	+ 1	+ 2	+ 4	+ 5	+ 6	+ 6	+ 6	+ 6
Summer May	+ 7	+ 7	+ 7	+ 6	+ 6	+ 7	+10	+ 8	+ 1	− 7	−13	−18	−15	− 9	− 4	0	+ 2	+ 4	+ 4	+ 4	+ 6	+ 7	+ 7	+ 8	+ 8	+ 8
Summer June	+ 5	+ 5	+ 6	+ 5	+ 6	+ 7	+10	+ 8	+ 2	− 5	−13	−22	−20	−15	− 9	− 4	+ 1	+ 4	+ 4	+ 4	+ 5	+ 7	+ 7	+ 7	+ 6	
Summer July	+ 5	+ 5	+ 5	+ 5	+ 6	+ 7	+11	+ 8	+ 2	− 5	−14	−20	−17	−13	−10	− 5	0	+ 3	+ 4	+ 4	+ 5	+ 7	+ 7	+ 7	+ 7	
Summer Aug.	+ 4	+ 5	+ 5	+ 5	+ 5	+ 6	+ 9	+ 7	+ 1	− 7	−13	−16	−14	−11	− 6	− 1	+ 1	+ 2	+ 3	+ 3	+ 5	+ 6	+ 7	+ 6	+ 6	
Summer Sep.	+ 3	+ 4	+ 3	+ 4	+ 3	+ 3	+ 4	+ 5	+ 3	− 2	−10	−16	−15	−11	− 5	− 1	0	+ 1	0	+ 1	+ 3	+ 3	+ 4	+ 5	+ 4	
Means	+ 5	+ 6	+ 5	+ 5	+ 5	+ 6	+ 8	+ 7	+ 2	− 5	−12	−18	−16	−12	− 7	− 2	+ 1	+ 3	+ 3	+ 3	+ 5	+ 6	+ 7	+ 7	+ 6	

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

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Hourly Means of the Dip at Dehra Dun in 1920, determined from all available days. Dip = N. 44° + tabular quantity.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan.	58·0	58·0	57·8	57·8	57·9	57·7	57·6	57·4	57·3	57·4	57·3	56·8	**56·8**	56·9	57·0	57·2	57·5	57·8	58·0	58·0	58·0	**58·2**	58·1	58·1	58·1	57·6
	Feb.	**58·6**	58·5	58·4	58·4	58·3	58·2	58·0	57·9	57·7	57·5	57·1	56·8	**56·6**	56·8	57·2	57·4	57·6	58·0	58·1	58·2	58·3	58·4	58·4	58·4	58·4	57 9
	Mar.	**59·9**	59·7	59·8	59·9	59·8	59·6	59·5	59·5	59·4	58·9	58·0	57·1	**56·9**	57·1	57·8	58·3	58·8	59·0	59·1	59·3	59·4	59·5	59·7	59·7	59·7	59·0
	Oct.	62·2	62·2	(2·2	62·0	62·0	61·9	61·8	62·1	62·1	61·9	61·5	60·8	**60·4**	60·4	60·8	61·4	61·8	62·2	62 2	62·3	**62·4**	62·2	62·1	62·1	61·9	61·8
	Nov.	62·1	62·0	61 9	61·8	61·8	61·7	61·6	61·6	61·6	61·4	61·2	**60·9**	61·0	61·2	61·4	61·8	62·1	62·2	62 3	62·3	62·5	**62·5**	62·5	62·5	62·1	61·8
	Dec.	62·2	62·3	62·1	61·9	61·8	61·7	61·6	61·7	61·7	61·6	61·5	**61·0**	61·0	61·2	61·4	61·6	61·8	62·1	62·3	**62·5**	62·4	62·3	62·2	62·3	62·2	61·8
Means		60·5	60·5	60·4	60·3	60·3	60·1	60·0	60·0	60·0	59·8	59·4	58·9	**58·8**	58·9	59·3	59·6	59·9	60·2	60·3	60·4	60·5	**60·5**	60·5	60·5	60·4	60·0
Summer.	April	60·2	60·1	60·0	60·0	60·0	59·9	59·9	60·2	**60·3**	59·8	58·9	58·2	57·8	**57·7**	58·3	59 0	59·5	60·0	60·1	60·1	60·2	60·1	60·1	60·0	60·0	59·6
	May	59·7	59·6	59·6	59·5	59·5	59·5	59·7	59·8	59·6	59·1	58·4	57·6	**57·6**	57·8	58·3	58·9	59·5	59·7	**59·9**	59·7	59·8	59·7	59·7	59·6	59·7	59·2
	June	59·4	**59·5**	**59·6**	59·5	59·5	59·5	59·5	59·5	59·5	59·2	58·5	57·9	**57·6**	57·7	58·0	58·5	58·9	59·4	59·6	59·5	59·5	59·5	59·5	59·5	59·5	59·1
	July	59·9	59·8	59·8	59·9	60·0	60·0	60·1	60·1	59·8	59·3	58·5	**57·9**	57·9	58·0	58·2	58·7	59·3	59·9	**60·2**	60·0	60·1	60·0	60·0	60·0	60·0	59·5
	Aug.	60·6	60·6	60·8	60·8	60·7	60·8	61·0	**61·1**	61·0	60·7	60·0	59·4	**59·2**	59·2	59·5	59·9	60·4	60·6	60·8	60·8	60 9	60·9	60·9	60·7	60·6	60·5
	Sep.	61·6	61·4	61·4	61·4	61·3	61·4	61·6	61·9	**62·2**	62·0	61·4	60·8	60·3	**60·2**	60·2	60·6	61·2	61·5	61·6	61·7	61·8	61·6	61·6	61·5	61·4	61·3
Means		60·2	60·2	60·2	60·2	60·2	60·2	60·3	**60·4**	60·4	60·0	59·3	58·6	**58·4**	58·4	58·8	59·3	59·8	60·2	60·4	60·3	60·4	60·3	60·3	60·2	60·2	59·9

Diurnal Inequality of the Dip at Dehra Dun in 1920, deduced from the above table.

Winter.	Jan.	+0′4	+0′4	+0′2	+0′2	+0′3	+0′1	0′0	−0′2	−0′3	−0′2	−0′3	−0′8	−0′8	−0′7	−0′6	−0′4	−0′1	+0′2	+0′4	+0′4	+0′4	+0′6	+0′5	+0′5	+0′5	
	Feb.	+0·7	+0·6	+0·5	+0·5	+0·4	+0·3	+0·1	0·0	−0·2	−0·4	−0·8	−1·1	−1·3	−1·1	−0·7	−0·5	−0·3	+0·1	+0·2	+0·3	+0·4	+0·5	+0·5	+0·5	+0·5	
	Mar.	+0·9	+0·7	+0·8	+0·9	+0·8	+0·6	+0·5	+0·5	+0·4	−0·1	−1·0	−1·9	−2·1	−1·9	−1·2	−0·7	−0·2	0·0	+0·1	+0·3	+0·4	+0·5	+0·7	+0·7	+0·7	
	Oct.	+0·4	+0·4	+0·4	+0·2	+0·2	+0·1	0·0	+0·3	−0·3	+0·1	+0·3	−1·0	−1·4	−1·4	−1·0	−0·4	0·0	+0·4	+0·4	+0·5	+0·6	+0·4	+0·3	+0·3	+0·1	
	Nov.	+0·3	+0·2	+0·1	0·0	0·0	−0·1	−0·2	−0·2	−0·2	−0·4	−0·6	−0·9	−0·8	−0·6	−0·4	0·0	+0·3	+0·4	+0·5	+0·5	+0·7	+0·7	+0·7	+0·7	+0·3	
	Dec.	+0·4	+0·5	+0·3	+0·1	0·0	−0·1	−0·2	−0·1	−0·1	−0·2	−0·3	−0·8	−0·8	−0·6	−0·4	−0·2	0·0	+0·3	+0·5	+0·7	+0·6	+0·5	+0 4	+0·5	+0·4	
Means		+0·5	+0·5	+0·4	+0·3	+0·3	+0·1	0·0	0·0	0·0	−0·2	−0·6	−1·1	−1·2	−1·1	−0·7	−0·4	−0·1	+0·2	+0·3	+0·4	+0·5	+0·5	+0·5	+0·5	+0·4	
Summer.	April	+0·6	+0·5	+0·4	+0·4	+0·4	+0·3	+0·3	+0·6	+0·7	+0·2	−0·7	−1·4	−1·8	−1·9	−1·3	−0·6	−0·1	+0·4	+0·5	+0·5	+0·6	+0·5	+0·5	+0·4	+0·4	
	May	+0·5	+0·4	+0·4	+0·3	+0·3	+0·5	+0·6	+0·4	−0·1	−0·8	−1·6	−1·6	−1·4	−0·9	−0·3	+0·3	+0·5	+0·7	+0·5	+0·6	+0·5	+0·5	+0·4	+0·5		
	June	+0·3	+0·4	+0·5	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·1	−0·6	−1·2	−1·5	−1·4	−1·1	−0·6	−0·2	+0·3	+0·5	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	
	July	+0·4	+0·3	+0·3	+0·4	+0·5	+0·5	+0·6	+0·6	+0·3	−0·2	−1·0	−1·6	−1·6	−1·5	−1·3	−0·8	−0·2	+0·4	+0·7	+0·5	+0·6	+0·5	+0·5	+0·5	+0·5	
	Aug.	+0·1	+0·1	+0·3	+0·3	+0·2	+0·3	+0·5	+0·6	+0·5	+0·2	−0·5	−1·1	−1·3	−1·3	−1·0	−0·6	−0·1	+0·1	+0·3	+0·3	+0·4	+0·4	+0·4	+0·2	+0·1	
	Sep.	+0·3	+0·1	+0·1	+0·1	0·0	+0·1	+0·3	+0·6	+0·9	+0·7	+0·1	−0·5	−1·0	−1·1	−1·1	−0·7	−0·1	+0·2	+0·3	+0·4	+0·5	+0·3	+0·3	+0·2	+0·1	
Means		+0·3	+0·3	+0·3	+0·3	+0·3	+0·3	+0·4	+0·5	+0·5	+0·1	−0·6	−1·3	−1·5	−1·5	−1·1	−0·6	−0·1	+0·3	+0·5	+0·4	+0·5	+0·4	+0·4	+0·3	+0·3	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

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Hourly Means of the Declination at Toungoo in 1920, determined from all available days. Declination = W. 0° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	22·0	22·1	22·3	22·5	22·6	22·8	23·1	**23·3**	22·7	21·6	**21·1**	21·7	22·5	22·8	23·0	22·6	22·1	21·8	22·0	21·9	21·9	22·0	22·0	**23·0**	22·0	22·3
Feb.	22·3	22·3	22·5	22·6	22·9	23·1	23·4	23·5	22·9	21·9	21·2	**21·1**	21·7	22·6	23·5	**23·6**	23·2	22·8	22·6	22·5	22·3	22·4	22·5	**23·4**	22·3	22·6
Mar.	22·8	22·8	22·8	22·9	23·0	23·1	23·1	22·5	21·8	**21·4**	21·7	22·3	23·0	23·7	**23·7**	23·1	22·6	22·4	22·8	22·9	22·8	22·9	22·9	22·8	22·8	22·7
Oct.	24·7	24·6	24·5	24·6	24·8	24·9	24·8	24·0	**23·6**	23·7	24·4	25·5	**26·0**	26·0	25·3	24·5	24·0	24·4	24·9	24·6	24·7	24·8	24·8	24·8	24·7	24·7
Nov.	24·9	24·9	25·0	25·0	25·1	25·2	25·1	24·8	24·3	**24·3**	24·9	25·3	**25·4**	25·0	24·7	24·4	24·3	24·7	24·9	24·8	24·7	24·9	24·9	24·9	24·9	24·8
Dec.	25·3	25·5	25·5	25·7	25·8	26·0	26·0	25·6	24·9	**24·3**	25·1	26·0	**26·2**	25·7	25·3	24·8	24·5	24·8	25·1	25·0	25·1	25·2	25·3	25·4	25·4	25·3
Means	23·7	23·7	23·8	23·9	24·0	24·2	24·3	24·0	23·4	**22·9**	23·1	23·7	24·1	**24·3**	24·3	23·8	23·5	23·5	23·7	23·6	23·6	23·7	23·7	23·7	23·7	23·7
Summer																										
April	22·9	22·7	22·5	22·6	22·7	22·8	22·2	21·4	**21·2**	21·8	22·6	23·9	24·8	**24·8**	24·5	24·0	23·2	22·8	22·9	23·1	23·2	23·2	23·1	23·0	22·9	23·0
May	23·5	23·2	23·1	23·1	23·1	23·0	21·7	**20·7**	20·9	22·2	23·8	24·9	**25·7**	25·6	25·1	24·3	23·5	23·2	23·2	23·7	24·0	24·0	23·9	23·7	23·5	23·5
June	23·5	23·3	23·1	23·0	22·9	22·8	21·7	20·9	**20·7**	21·5	22·8	24·3	25·3	**25·5**	25·5	25·1	24·3	23·7	23·4	23·7	23·9	23·9	23·8	23·6	23·5	23·4
July	23·8	23·5	23·3	23·3	23·2	23·0	21·9	**20·9**	21·0	22·0	23·1	24·2	25·0	**25·3**	25·2	25·0	24·2	23·7	23·6	23·9	24·1	24·2	24·1	23·9	23·8	23·6
Aug.	24·0	23·9	23·8	23·7	23·5	23·3	22·0	**21·0**	21·0	22·5	24·2	25·5	**26·0**	26·0	25·7	25·1	24·3	23·7	23·9	24·2	24·3	24·4	24·3	24·2	24·0	23·9
Sep.	24·5	24·3	24·2	24·2	24·1	24·1	23·3	22·3	**22·2**	23·3	24·8	26·1	**26·9**	26·7	26·0	25·0	24·1	23·9	24·5	24·5	24·7	24·8	24·7	24·7	24·5	24·5
Means	23·7	23·5	23·3	23·3	23·3	23·2	22·1	21·2	**21·2**	22·2	23·6	24·8	25·6	**25·7**	25·3	24·8	23·9	23·5	23·6	23·9	24·0	24·1	24·0	23·9	23·7	23·7

Diurnal Inequality of the Declination at Toungoo in 1920, deduced from the above table.

	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter																										
Jan.	+0′3	+0′2	0′0	−0′2	−0′3	−0′5	−0′8	−1′0	−0′4	+0′7	+1′2	+0′6	−0′2	−0′5	−0′7	−0′3	+0′2	+0′5	+0′3	+0′4	+0′4	+0′3	+0′3	+0′3	+0′3	
Feb.	+0·3	+0·3	+0·1	0·0	−0·3	−0·5	−0·8	−0·9	−0·3	+0·7	+1·4	+1·5	+0·9	0·0	−0·9	−1·0	−0·6	−0·2	0·0	+0·1	+0·3	+0·2	+0·1	+0·2	+0·3	
Mar.	−0·1	−0·1	−0·1	−0·2	−0·3	−0·4	−0·4	+0·2	+0·9	+1·3	+1·0	+0·4	−0·3	−1·0	−1·0	−0·4	+0·1	+0·3	−0·1	−0·2	−0·1	−0·2	−0·2	−0·1	−0·1	
Oct.	0·0	+0·1	+0·2	+0·1	−0·1	−0·2	−0·1	+0·7	+1·1	+1·0	+0·3	−0·8	−1·3	−1·3	−0·6	+0·2	+0·7	+0·3	−0·2	+0·1	0·0	−0·1	−0·1	−0·1	0·0	
Nov.	−0·1	−0·1	−0·2	−0·2	−0·3	−0·4	−0·3	0·0	+0·5	+0·5	−0·1	−0·5	−0·6	−0·2	+0·1	+0·4	+0·5	+0·1	−0·1	0·0	+0·1	−0·1	−0·1	−0·1	−0·1	
Dec.	0·0	−0·2	−0·2	−0·4	−0·5	−0·7	−0·7	−0·3	+0·4	+1·0	+0·2	−0·7	−0·9	−0·4	0·0	+0·5	+0·8	+0·5	+0·2	+0·3	+0·2	+0·1	0·0	−0·1	−0·1	
Means	0·0	0·0	−0·1	−0·2	−0·3	−0·5	−0·6	−0·3	+0·3	+0·8	+0·6	0·0	−0·4	−0·6	−0·6	−0·1	+0·2	+0·2	0·0	+0·1	+0·1	0·0	0·0	0·0	0·0	
Summer																										
April	+0·1	+0·3	+0·5	+0·4	+0·3	+0·2	+0·8	+1·6	+1·8	+1·2	+0·4	−0·9	−1·8	−1·8	−1·5	−1·0	−0·2	+0·2	+0·1	−0·1	−0·2	−0·2	−0·1	0·0	+0·1	
May	0·0	+0·3	+0·4	+0·4	+0·4	+0·5	+1·8	+2·8	+2·6	+1·3	−0·3	−1·4	−2·2	−2·1	−1·6	−0·8	0·0	+0·3	+0·3	−0·2	−0·5	−0·5	−0·4	−0·2	0·0	
June	−0·1	+0·1	+0·3	+0·4	+0·5	+0·6	+1·7	+2·5	+2·7	+1·9	+0·6	−0·9	−1·9	−2·1	−2·1	−1·7	−0·9	−0·3	0·0	−0·3	−0·5	−0·5	−0·4	−0·2	−0·1	
July	−0·2	+0·1	+0·3	+0·3	+0·4	+0·6	+1·7	+2·7	+2·6	+1·6	+0·5	−0·6	−1·4	−1·7	−1·6	−1·4	−0·6	−0·1	0·0	−0·3	−0·5	−0·6	−0·5	−0·3	−0·2	
Aug.	−0·1	0·0	+0·1	+0·2	+0·4	+0·6	+1·9	+2·9	+2·9	+1·4	−0·3	−1·6	−2·1	−2·1	−1·8	−1·2	−0·4	+0·2	0·0	−0·3	−0·4	−0·5	−0·4	−0·3	−0·1	
Sep.	0·0	+0·2	+0·3	+0·3	+0·4	+0·4	+1·2	+2·2	+2·3	+1·2	−0·3	−1·6	−2·4	−2·2	−1·5	−0·5	+0·4	+0·6	0·0	0·0	−0·2	−0·3	−0·2	−0·2	0·0	
Means	0·0	+0·2	+0·4	+0·4	+0·4	+0·5	+1·6	+2·5	+2·5	+1·5	+0·1	−1·1	−1·9	−2·0	−1·6	−1·1	−0·2	+0·2	+0·1	−0·2	−0·3	−0·4	−0·3	−0·2	0·0	

NOTE.—When the sign is + the magnet points to the east, and when − to the west of the mean position.

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Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Toungoo in 1920, from all available days. Horizontal Force = ·39000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	096	095	097	100	100	100	103	109	114	122	125	128	126	123	118	112	104	100	096	094	095	094	093	094	096	106
	Feb.	095	094	099	100	101	103	105	111	118	127	136	143	144	139	131	121	114	109	105	104	101	100	101	101	101	113
	Mar.	085	088	089	088	088	088	092	098	109	123	139	149	152	143	130	115	105	101	099	099	096	094	094	092	094	107
	Oct.	099	098	099	100	103	104	106	105	110	123	134	144	144	138	128	117	105	100	097	097	093	093	097	099	102	110
	Nov.	108	111	114	116	118	119	120	122	127	135	143	148	146	140	132	125	116	113	111	110	108	106	106	108	108	121
	Dec.	119	121	123	125	127	131	133	138	142	147	155	158	157	151	145	138	130	127	127	122	119	119	122	123	123	133
	Means	100	101	104	105	106	108	110	114	120	130	139	145	145	139	131	121	112	108	106	104	102	101	102	103	104	115
Summer	April	089	091	092	094	094	096	098	100	108	120	133	142	143	137	128	114	100	092	092	092	092	090	093	094	094	105
	May	104	103	107	107	107	108	110	112	120	130	141	145	143	138	128	118	107	099	098	100	101	103	104	104	106	114
	June	115	117	116	116	116	117	121	125	132	140	151	161	160	155	145	134	123	117	116	117	118	118	118	119	119	128
	July	109	108	109	109	108	108	111	117	124	132	142	146	148	144	136	126	115	108	104	105	107	107	108	108	108	118
	Aug.	102	103	104	102	102	103	104	107	111	119	126	131	133	129	122	116	109	100	099	101	099	099	101	101	103	109
	Sep.	096	097	099	100	100	101	099	095	095	104	117	126	129	126	119	111	103	096	095	095	094	093	096	096	098	103
	Means	103	103	105	105	105	106	107	109	115	124	135	142	143	138	130	120	110	102	101	102	102	102	103	104	105	113

Diurnal Inequality of the Horizontal Force at Toungoo in 1920, deduced from the above table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter	Jan.	−10	−11	− 9	− 6	− 6	− 6	− 3	+ 3	+ 8	+16	+19	+22	+20	+17	+12	+ 6	− 2	− 6	−10	−12	−11	−12	−13	−12	−10	
	Feb.	−18	−19	−14	−13	−12	−10	− 8	− 2	+ 5	+14	+23	+30	+31	+26	+18	+ 8	+ 1	− 4	− 8	− 9	−12	−13	−12	−12	−12	
	Mar.	−22	−19	−18	−19	−19	−19	−15	− 9	+ 2	+16	+32	+42	+45	+36	+23	+ 8	− 2	− 6	− 8	− 8	−11	−13	−13	−15	−13	
	Oct.	−11	−12	−11	−10	− 7	− 6	− 4	− 5	0	+13	+24	+34	+34	+28	+18	+ 7	− 5	−10	−13	−13	−17	−17	−13	−11	− 8	
	Nov.	−13	−10	− 7	− 5	− 3	− 2	− 1	+ 1	+ 6	+14	+22	+27	+25	+19	+11	+ 4	− 5	− 8	−10	−11	−13	−15	− 15	−13	−13	
	Dec.	−14	−12	−10	− 8	− 6	− 2	0	+ 5	+ 9	+14	+22	+25	+24	+18	+12	+ 5	− 3	− 6	− 6	−11	−14	−14	−11	−10	−10	
	Means	−15	−14	−11	−10	− 9	− 7	− 5	− 1	+ 5	+15	+24	+30	+30	+24	+16	+ 6	− 3	− 7	− 9	−11	−13	−14	−13	−12	−11	
Summer	April	−16	−14	−13	−11	−11	− 9	− 7	− 5	+ 3	+15	+28	+37	+38	+32	+23	+ 9	− 5	−13	−13	−13	−13	−15	−12	−11	−11	
	May	−10	−11	− 7	− 7	− 7	− 6	− 4	− 2	+ 6	+16	+27	+31	+29	+24	+14	+ 4	− 7	−15	−16	−14	−13	−11	−10	−10	− 8	
	June	−13	−11	−12	−12	−12	−11	− 7	− 3	+ 4	+12	+23	+33	+32	+27	+17	+ 6	− 5	−11	−12	−11	−10	−10	−10	− 9	− 9	
	July	− 9	−10	− 9	− 9	−10	−10	− 7	− 1	+ 6	+14	+24	+28	+30	+26	+18	+ 8	− 3	−10	−14	−13	−11	−11	−10	−10	−10	
	Aug.	− 7	− 6	− 5	− 7	− 7	− 6	− 5	− 2	+ 2	+10	+17	+22	+24	+20	+13	+ 7	0	− 9	−10	− 8	−10	−10	− 8	− 8	− 6	
	Sep.	− 7	− 6	− 4	− 3	− 3	− 2	− 4	− 8	− 8	+ 1	+14	+23	+26	+23	+16	+ 8	0	− 7	− 8	− 8	− 9	−10	− 7	− 7	− 5	
	Means	−10	−10	− 8	− 8	− 8	− 7	− 6	− 4	+ 2	−11	+22	+29	+30	+25	+17	+ 7	− 3	−11	−12	−11	−11	−11	−10	− 9	− 8	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean

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Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Toungoo in 1920, from all available days. Vertical Force = ·16000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	707	707	706	706	706	706	706	706	708	707	700	692	687	691	694	700	704	704	703	704	705	705	706	706	707	703
	Feb.	713	713	712	712	712	711	711	712	713	711	707	703	696	693	694	699	704	708	708	709	710	711	711	712	713	708
	Mar.	708	708	708	708	707	707	708	708	704	698	691	690	689	693	699	702	703	702	702	704	705	705	706	707	708	703
	Oct.	709	710	710	710	709	709	711	711	705	697	689	687	690	696	703	706	705	703	704	706	707	708	709	709	710	704
	Nov.	711	711	711	711	712	712	712	712	708	701	696	696	699	701	704	706	706	704	707	708	709	710	711	711	711	707
	Dec.	712	712	712	712	712	713	713	714	712	703	694	695	700	706	709	712	710	709	710	711	712	712	712	713	713	709
	Means	710	710	710	710	710	710	710	711	708	703	696	694	694	697	701	704	705	705	706	707	708	709	709	710	710	706
Summer	April	715	715	715	715	714	714	717	715	707	700	695	693	697	704	710	713	714	712	710	711	711	712	713	714	715	710
	May	712	712	712	712	711	712	716	713	704	694	690	690	693	700	705	709	711	709	708	708	709	710	711	711	712	707
	June	716	716	716	716	716	717	720	718	712	704	697	695	699	703	707	711	715	715	714	712	714	714	715	716	716	712
	July	714	715	714	714	714	715	718	715	709	702	699	698	701	704	706	708	713	712	711	710	711	712	713	714	714	710
	Aug.	710	710	710	710	711	711	716	713	705	696	692	694	696	701	704	708	710	709	707	707	708	708	709	710	710	706
	Sep.	710	711	711	711	711	711	715	713	703	690	685	684	688	697	705	710	710	707	705	707	708	708	709	710	711	705
	Means	713	713	713	713	713	713	717	715	707	698	693	692	696	702	706	710	712	711	709	709	710	711	712	713	713	708

Diurnal Inequality of the Vertical Force at Toungoo in 1920, deduced from the above table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	+ 4	+ 4	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	+ 5	+ 4	− 3	−11	−16	−12	− 9	− 3	+ 1	+ 1	0	+ 1	+ 2	+ 2	+ 3	+ 3	+ 4	
	Feb.	+ 5	+ 5	+ 4	+ 4	+ 4	+ 3	+ 3	+ 4	+ 5	+ 3	− 1	− 5	−12	−15	−14	− 9	− 4	0	0	+ 1	+ 2	+ 3	+ 3	+ 4	+ 5	
	Mar.	+ 5	+ 5	+ 5	+ 5	+ 4	+ 4	+ 5	+ 5	+ 1	− 5	−12	−13	−14	−10	− 4	− 1	0	− 1	− 1	+ 1	+ 2	+ 2	+ 3	+ 4	+ 5	
	Oct.	+ 5	+ 6	+ 6	+ 6	+ 5	+ 5	+ 7	+ 7	+ 1	− 7	−15	−17	−14	− 8	− 1	+ 2	+ 1	− 1	0	+ 2	+ 3	+ 4	+ 5	+ 5	+ 6	
	Nov.	+ 4	+ 4	+ 4	+ 4	+ 5	+ 5	+ 5	+ 5	+ 1	− 6	−11	−11	− 8	− 6	− 3	− 1	− 1	− 3	0	+ 1	+ 2	+ 3	+ 4	+ 4	+ 4	
	Dec.	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4	+ 4	+ 5	+ 3	− 6	−15	−14	− 9	− 3	0	+ 3	+ 1	0	+ 1	+ 2	+ 3	+ 3	+ 3	+ 4	+ 4	
	Means	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 2	− 3	−10	−12	−12	− 9	− 5	− 2	− 1	− 1	0	+ 1	+ 2	+ 3	+ 3	+ 4	+ 4	
Summer	April	+ 5	+ 5	+ 5	+ 5	+ 4	+ 4	+ 7	+ 5	− 3	−10	−15	−17	−13	− 6	0	+ 3	+ 4	+ 2	0	+ 1	+ 1	+ 2	+ 3	+ 4	+ 5	
	May	+ 5	+ 5	+ 5	+ 5	+ 4	+ 5	+ 9	+ 6	− 3	−13	−17	−17	−14	− 7	− 2	+ 2	+ 4	+ 2	+ 1	+ 1	+ 2	+ 3	+ 4	+ 4	+ 5	
	June	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 6	0	− 8	−15	−17	−13	− 9	− 5	− 1	+ 3	+ 3	+ 2	0	+ 2	+ 2	+ 3	+ 4	+ 4	
	July	+ 4	+ 5	+ 4	+ 4	+ 4	+ 5	+ 8	+ 5	− 1	− 8	− 1	−12	− 9	− 6	− 4	− 2	+ 3	+ 2	+ 1	0	+ 1	+ 2	+ 3	+ 4	+ 4	
	Aug.	+ 4	+ 4	+ 4	+ 4	+ 5	+ 5	+10	+ 7	− 1	−10	−14	−12	−10	− 5	− 2	+ 2	+ 4	+ 3	+ 1	+ 1	+ 2	+ 2	+ 3	+ 4	+ 4	
	Sep.	+ 5	+ 6	+ 6	+ 6	+ 6	+ 6	+10	+ 8	− 2	−15	−20	−21	−17	− 8	0	+ 5	+ 5	+ 2	0	+ 2	+ 3	+ 3	+ 4	+ 5	+ 6	
	Means	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 9	+ 7	− 1	−10	−15	−16	−12	− 6	− 2	+ 2	+ 4	+ 3	+ 1	+ 1	+ 2	+ 3	+ 4	+ 5	+ 5	

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

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Hourly Means of the Dip at Toungoo in 1920, determined from all available days. Dip = N. 23° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	8·3	8·4	8·2	8·1	8·1	8·1	8·0	7·8	7·8	7·5	6·9	6·2	5·9	6·3	6·6	7·3	7·8	8·0	8·0	8·2	8·2	8·2	8·3	8·3	8·3	7·7
Feb.	8·8	8·8	8·6	8·6	8·5	8·4	8·3	8·2	8·0	7·6	7·0	6·5	6·0	5·9	6·2	6·9	7·5	8·0	8·1	8·2	8·4	8·5	8·5	8·5	8·6	7·8
Mar.	8·7	8·7	8·6	8·7	8·6	8·6	8·5	8·3	7·7	6·8	5·8	5·4	5·2	5·8	6·6	7·4	7·7	7·8	7·8	8·0	8·2	8 2	8·3	8·5	8·5	7·7
Oct.	8·4	8·5	8·5	8·4	8·2	8·2	8·3	8·3	7·7	6·7	5·8	5·3	5·5	6·2	7·0	7·6	7·9	7·9	8·1	8·2	8·4	8·5	8·5	8·4	8·4	7·7
Nov.	8·2	8·1	8·0	8·0	8·0	8·0	7·9	7·9	7·4	6·6	6·0	5·8	6·1	6·5	7·0	7·3	7·6	7·6	7·8	7·9	8·1	8·2	8·3	8·2	8·2	7·5
Dec.	8·0	7·9	7·8	7·8	7·7	7·6	7·6	7·5	7·2	6·4	5·5	5·5	5·9	6·5	6·9	7·4	7·5	7·5	7·6	7·8	8·0	8·0	7·9	7·9	7·9	7·3
Means	8·4	8·4	8·3	8·3	8·2	8·2	8·1	8·0	7·6	6·9	6·2	5·8	5·8	6·2	6·7	7·3	7·7	7·8	7·9	8·1	8·2	8·3	8·3	8·3	8·3	7·6
Summer. April	9·2	9·1	9·1	9·0	8·9	8·9	9·0	8·8	7·9	7·0	6·3	5·8	6·1	6·8	7·5	8·2	8·7	8·8	8·7	8·7	8·7	8·9	8·9	8·9	9·0	8·2
May	8·5	8·5	8·4	8·4	8·3	8·3	8·5	8·2	7·3	6·3	5·6	5·5	5·8	6·5	7·2	7·8	8·3	8·4	8·3	8·2	8·3	8·3	8·4	8·4	8·4	7·7
June	8·4	8·3	8·4	8·4	8·4	8·4	8·5	8·2	7·6	6·7	5·8	5·4	5·7	6·1	6·8	7·4	8·1	8·2	8·2	8·0	8·1	8·1	8·2	8·2	8·2	7·7
July	8·4	8·5	8·4	8·4	8·5	8·5	8·7	8·2	7·6	6·8	6·3	6·0	6·2	6·6	7·0	7·4	8·2	8·3	8·4	8·3	8·3	8·4	8·4	8·5	8·5	7·8
Aug.	8·4	8·3	8·3	8·4	8·4	3·4	8·7	8·4	7·7	6·8	6·2	6·2	6·3	6·8	7·3	7·8	8·1	8·3	8·2	8·2	8·3	8·3	8·3	8·4	8·3	7·9
Sep.	8·6	8·6	8·5	8·5	8·5	8·5	8·8	8·8	8·0	6·8	6·0	5·6	5·8	6·6	7·4	8·1	8·3	8·3	8·2	8·4	8·5	8·5	8·5	8·6	8·6	7·9
Means	8·6	8·6	8·5	8·5	8·5	8·5	8·7	8·4	7·7	6·7	6·0	5·8	6·0	6·6	7·2	7·8	8·3	8·4	8·3	8·3	8·4	8·4	8·5	8·5	8·5	7·9

Diurnal Inequality of the Dip at Toungoo in 1920, deduced from the above table.

	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	+0·6	+0·7	+0·5	+0·4	+0·4	+0·4	+0·3	+0·1	+0·1	−0·2	−0·8	−1·5	−1·8	−1·4	−1·1	−0·4	+0·1	+0·3	+0·3	+0·5	+0·5	+0·5	+0·6	+0·6	+0·6	
Feb.	+1·0	+1·0	+0·8	+0·8	+0·7	+0·6	+0·5	+0·4	+0·2	−0·2	−0·8	−1·3	−1·8	−1·9	−1·6	−0·9	−0·3	+0·2	+0·3	+0·4	+0·6	+0·7	+0·7	+0·7	+0·8	
Mar.	+1·0	+1·0	+0·9	+1·0	+0·9	+0·9	+0·8	+0·6	0·0	−0·9	−1·9	−2·3	−2·5	−1·9	−1·1	−0·3	0·0	+0·1	+0·1	+0·3	+0·5	+0·5	+0·6	+0·8	+0·8	
Oct.	+0·7	+0·8	+0·8	+0·7	+0·5	+0·5	+0·6	+0·6	0·0	−1·0	−1·9	−2·4	−2·2	−1·5	−0·7	−0·1	+0·2	+0·2	+0·4	+0·5	+0·7	+0·8	+0·8	+0·7	+0·7	
Nov.	+0·7	+0·6	+0·5	+0·5	+0·5	+0·5	+0·4	+0·4	−0·1	−0·9	−1·5	−1·7	−1·4	−1·0	−0·5	−0·2	+0·1	+0·1	+0·3	+0·4	+0·6	+0·7	+0·8	+0·7	+0·7	
Dec.	+0·7	+0·6	+0·5	+0·5	+0·4	+0·3	+0·3	+0·2	−0·1	−0·9	−1·8	−1·8	−1·4	−0·8	−0·4	+0·1	+0·2	+0·2	+0·3	+0·5	+0·7	+0·7	+0·6	+0·6	+0·6	
Means	+0·8	+0·8	+0·7	+0·7	+0·6	+0·6	+0·5	+0·4	0·0	−0·7	−1·4	−1·8	−1·8	−1·4	−0·9	−0·3	+0·1	+0·2	+0·3	+0·5	+0·6	+0·7	+0·7	+0·7	+0·7	
Summer. April	+1·0	+0·9	+0·9	+0·8	+0·7	+0·7	+0·8	+0·6	−0·3	−1·2	−1·9	−2·4	−2·1	−1·4	−0·7	0·0	+0·5	+0·6	+0·5	+0·5	+0·5	+0·7	+0·7	+0·7	+0·8	
May	+0·8	+0·8	+0·7	+0·7	+0·6	+0·6	+0·8	+0·5	−0·4	−1·4	−2·1	−2·2	−1·9	−1·2	−0·5	+0·1	+0·6	+0·7	+0·6	+0·5	+0·6	+0·6	+0·7	+0·7	+0·7	
June	+0·7	+0·6	+0·7	+0·7	+0·7	+0·7	+0·8	+0·5	−0·1	−1·0	−1·9	−2·3	−2·0	−1·6	−0·9	−0·3	+0·4	+0·5	+0·5	+0·3	+0·4	+0·4	+0·5	+0·5	+0·5	
July	+0·6	+0·7	+0·6	+0·6	+0·7	+0·7	+0·9	+0·4	−0·2	−1·0	−1·5	−1·8	−1·6	−1·2	−0·8	−0·4	+0·4	+0·5	+0·6	+0·5	+0·5	+0·6	+0·6	+0·7	+0·7	
Aug.	+0·5	+0·4	+0·4	+0·5	+0·5	+0·5	+0·8	+0·5	−0·2	−1·1	−1·7	−1·7	−1·6	−1·1	−0·6	−0·1	+0·2	+0·4	+0·3	+0·3	+0·4	+0·4	+0·4	+0·5	+0·4	
Sep.	+0·7	+0·7	+0·6	+0·6	+0·6	+0·6	+0·9	+0·9	+0·1	−1·1	−1·9	−2·3	−2·1	−1·3	−0·5	+0·2	+0·4	+0·4	+0·3	+0·5	+0·6	+0·6	+0·6	+0·7	+0·7	
Means	+0·7	+0·7	+0·6	+0·6	+0·6	+0·6	+0·8	+0·5	−0·2	−1·2	−1·9	−2·1	−1·9	−1·3	−0·7	−0·1	+0·4	+0·5	+0·4	+0·4	+0·5	+0·5	+0·6	+0·6	+0·6	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

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Hourly Means of the Declination at Kodaikanal in 1920, determined from all available days. Declination = W. 1° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter	Jan.	47 3	47·3	47·4	47·5	47·8	48·0	48·3	**48·5**	48·2	47·4	**47·0**	47·1	47·5	47·8	47·9	47·6	47·3	47·1	47·1	47·0	47·0	47·1	47·2	47·2	47·3	47·5
	Feb.	47·8	47·8	47·9	48·1	48·2	48·5	48·8	**49·0**	48·5	47·6	46·9	**46·9**	47·1	47·3	47·8	48·2	48·2	48·0	47·9	47·8	47·7	47·8	47·9	47·9	47·9	47·9
	Mar.	48·0	47·9	47·9	48·1	48·2	48·2	48·2	48·0	47·7	**47·5**	47·7	48·0	48·4	**48·6**	48·4	47·9	47·5	47·5	47·7	47·9	48·0	48·0	48·1	48·0	48·0	48·0
	Oct.	51·4	51·4	51·3	51·4	51·5	51·6	51·4	51·2	51·1	51·3	51·9	**52·5**	52·4	52·0	51·6	51·1	**50·8**	51·1	51·3	51·3	51·5	51·5	51·6	51·5	51·5	51·5
	Nov.	51·9	52·0	52·1	52·2	52·3	52·3	52·2	52·1	51·8	51·9	52·4	**52·6**	52·3	51·7	51·3	**51·1**	51·1	51·5	51·6	51·4	51·6	51·7	51·8	51·8	51·9	51·9
	Dec.	52·4	52·5	52·7	52·8	52·9	53·0	**53·1**	53·1	52·5	52·2	52·4	52·8	52·6	52·0	51·6	**51·3**	51·3	51·8	51·9	51·9	52·0	52·2	52·3	52·4	52·4	52·3
	Means	49·8	49·8	49·9	50·0	50·2	50·3	**50·3**	50·3	50·0	49·7	49·7	50·0	50·1	49·9	49·8	49·5	**49·4**	49·5	49·6	49·6	49·6	49·7	49·8	49·8	49·8	49·9
Summer	April	48·4	48·3	48·2	48·2	48 2	48·3	48·1	**47·4**	47·5	48·0	48·6	49·5	50·0	**50·1**	49·5	49·0	48·4	48·3	48·4	48·6	48·8	48·8	48·7	48·6	48·4	48·6
	May	49·0	48·9	48·8	48·8	48·7	48·6	47·9	**47·3**	47·4	48·3	49·4	50·3	**50·7**	50·6	49·9	49·3	48·8	48·6	48·8	49·3	49·5	49·5	49·4	49·3	49·1	49·0
	June	49·7	49·6	49·5	49·4	49·3	49·2	48·5	**47·8**	47·9	48·5	49·7	50·7	51·8	**51·8**	51·3	50·7	50·1	49·9	49·8	50·1	50·2	50·1	50·0	49·9	49·7	49·8
	July	50·5	50·3	50·2	50·1	50·1	50·0	49·3	**48·5**	48·6	49·5	50·9	51·7	52·3	**52·4**	52·1	51·5	51·0	50·7	50·5	50·9	51·1	51·0	50·8	50·7	50·5	50·6
	Aug.	50·9	50·7	50 6	50·6	50·5	50·3	49·4	**48·7**	48·9	50·2	51·5	52·5	**53·0**	52·9	52·5	51·8	51·1	50·6	50·6	51·1	51·2	51·3	51·2	51·1	50·9	51·0
	Sep.	51·2	51·0	50·9	50·8	50·7	50·7	49·9	**49·1**	49·2	50·2	51·3	52·3	**52·9**	52·8	52·1	51·1	50·4	50·4	50·8	51·1	51·2	51·2	51·2	51·2	51·2	51·0
	Means	50·0	49·8	49·7	49·7	49·6	49·5	48·9	**48·1**	48·3	49·1	50·2	51·2	**51·8**	51·8	51·2	50·6	50·0	49·8	49·8	50·2	50·3	50·3	50·2	50·1	50·0	50·0

Diurnal Inequality of the Declination at Kodaikanal in 1920, deduced from the above table.

Winter	Jan.	+0·2	+0·2	+0·1	0·0	−0·8	−0·5	−0·8	−1·0	−0·7	+0·1	+0·5	+0·4	0·0	−0·3	−0·4	−0·1	+0·2	+0·4	+0·4	+0·5	+0·5	+0·4	+0·3	+0·3	+0·2	
	Feb.	+0·1	+0·1	0·0	−0·2	−0·3	−0·6	−0·9	−1·1	−0·6	+0·3	+1·0	+1·0	+0·8	+0·6	+0·1	−0·3	−0·3	−0·1	0·0	+0·1	+0·2	+0·1	0·0	0·0	0·0	
	Mar.	0·0	+0·1	+0·1	−0·1	−0·2	−0·2	−0·2	0·0	+0·3	+0·5	+0·3	0·0	−0·4	−0·6	−0·4	+0·1	+0·5	+0·5	+0·3	+0·1	0·0	0·0	−0·1	0·0	0·0	
	Oct.	+0·1	+0·1	+0·2	+0·1	0·0	−0·1	+0·1	+0·3	+0·4	+0·2	−0·4	−1·0	−0·9	−0·5	−0·1	+0·4	+0·7	+0·4	+0·2	+0·2	0·0	0·0	−0·1	0·0	0·0	
	Nov.	0·0	−0·1	−0·2	−0·3	−0·4	−0·4	−0·3	−0·2	+0·1	0·0	−0·5	−0·7	−0·4	+0·2	+0·6	+0·8	+0·8	+0·4	+0·3	+0·5	+0·3	+0·2	+0·1	+0·1	0·0	
	Dec.	−0·1	−0·2	−0·4	−0·5	−0·6	−0·7	−0·8	−0·8	−0·2	+0·1	−0·1	−0·5	−0·3	+0·3	+0·7	+1·0	+1·0	+0·5	+0·4	+0·4	+0·3	+0·1	0·0	−0·1	−0·1	
	Means	+0·1	+0·1	0·0	−0·1	−0·3	−0·4	−0·4	−0·4	−0·1	+0·2	+0·2	−0·1	−0·2	0·0	+0·1	+0·4	+0·5	+0·4	+0·3	+0·3	+0·3	+0·2	+0·1	+0·1	+0·1	
Summer	April	+0·2	+0·3	+0·4	+0·4	+0·4	+0·3	+0·5	+1·2	+1·1	+0·6	0·0	−0·9	−1·4	−1·5	−0·9	−0·4	+0·2	+0·3	+0·2	0·0	−0·2	−0·2	−0·1	0·0	+0·2	
	May	0·0	+0·1	+0·2	+0·2	+0·3	+0·4	+1·1	+1·7	+1·6	+0·7	−0·4	−1·3	−1·7	−1·6	−0·9	−0·3	+0·2	+0·4	+0·2	−0·3	−0·5	−0·5	−0·4	−0·3	−0·1	
	June	+0·1	+0·2	+0·3	+0·4	+0·5	+0·6	+1·3	+2·0	+1·9	+1·3	+0·1	−0·9	−2·0	−2·0	−1·5	−0·9	−0·3	−0·1	0·0	−0·3	−0·4	−0·3	−0·2	−0·1	+0·1	
	July	+0·1	+0·3	+0·4	+0·5	+0·5	+0·6	+1·3	+2·1	+2·0	+1·1	−0·3	−1·1	−1·7	−1·8	−1·5	−0·9	−0·4	−0·1	+0·1	−0·3	−0·5	−0·4	−0·2	−0·1	+0·1	
	Aug.	+0·1	+0·3	+0·4	+0·4	+0·5	+0·7	+1·6	+2·3	+2·1	+0·8	−0·5	−1·5	−2·0	−1·9	−1·5	−0·8	−0·1	+0·4	+0·4	−0·1	−0·2	−0·3	−0·2	−0·1	+0·1	
	Sep.	−0·2	0·0	+0·1	+0·2	+0·3	+0·3	+1·1	+1·9	+1·8	+0·8	−0·3	−1·3	−1·9	−1·8	−1·1	−0·1	+0·6	+0·6	+0·2	−0·1	−0·2	−0·2	−0·2	−0·2	−0·2	
	Means	0·0	+0·2	+0·3	+0·3	+0·4	+0·5	+1·1	+1·9	+1·7	+0·9	−0·2	−1·2	−1·8	−1·8	−1·2	−0·6	0·0	+0·2	+0·2	−0·2	−0·3	−0·3	−0·2	−0·1	0·0	

NOTE.—When the sign is + the magnet points to the east, and when − to the west of the mean position.

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Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1920, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	755	757	759	759	759	761	763	766	778	792	809	820	**824**	818	802	787	774	767	761	759	757	755	754	**754**	755	775
	Feb.	**752**	757	756	758	759	762	764	771	784	802	816	**828**	828	824	815	802	789	775	768	762	759	758	757	755	755	779
	Mar.	**738**	739	740	739	741	**744**	746	756	777	809	828	**842**	829	806	785	772	767	766	760	752	749	746	743	743	742	767
	Oct.	**772**	774	776	780	781	782	782	790	813	838	858	**866**	854	835	816	798	789	786	782	775	773	775	775	775	776	798
	Nov.	781	783	786	787	788	788	789	797	815	832	847	**849**	835	820	808	799	795	793	787	783	779	**776**	777	776	781	799
	Dec.	788	**788**	791	793	795	796	797	803	821	844	860	**862**	849	827	809	798	797	798	795	791	789	788	788	788	791	806
	Means	**764**	766	768	769	771	772	774	781	798	820	836	**845**	837	822	806	793	785	781	776	770	768	766	766	765	767	787
Summer	April	**743**	746	749	749	749	750	749	755	775	800	820	**827**	817	799	777	759	752	753	753	750	748	747	747	746	747	765
	May	758	762	762	762	762	762	764	773	793	817	**831**	830	820	804	786	771	764	763	761	759	758	758	**758**	759	760	777
	June	776	775	**775**	776	776	777	781	786	797	817	833	**842**	837	824	804	788	779	776	776	777	777	777	776	776	777	791
	July	781	783	783	783	782	783	786	792	805	821	831	**836**	829	821	806	792	783	**779**	781	782	781	781	781	780	781	794
	Aug.	785	786	784	**784**	785	785	787	791	807	824	832	**835**	825	813	800	791	782	782	785	783	782	**781**	783	**784**	786	795
	Sep.	773	777	777	780	779	779	778	782	805	833	**855**	855	839	813	793	781	776	779	780	775	**773**	775	774	**775**	777	792
	Means	**769**	772	772	772	772	773	774	780	797	819	834	**838**	828	812	794	780	773	772	773	771	770	770	770	770	771	786

Diurnal Inequality of the Horizontal Force at Kodaikanal in 1920, deduced from the above table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter	Jan.	−20	−18	−16	−16	−16	−14	−12	− 9	+ 3	+17	+34	+45	+49	+43	+27	+12	− 1	− 8	−14	−16	−18	−20	−21	−21	−20	
	Feb.	−27	−22	−23	−21	−20	−17	−15	− 8	+ 5	+23	+37	+49	+49	+45	+36	+23	+10	− 4	−11	−17	−20	−21	−22	−24	−24	
	Mar.	−29	−28	−27	−28	−26	−23	−21	−11	+10	+42	+61	+75	+62	+39	+18	+ 5	0	− 1	− 7	−15	−18	−21	−24	−24	−25	
	Oct.	−26	−24	−22	−18	−17	−16	−16	− 8	+15	+40	+60	+68	+56	+37	+18	0	− 9	−12	−16	−23	−25	−23	−23	−23	−22	
	Nov.	−18	−16	−13	−12	−11	−11	−10	− 2	+16	+33	+48	+50	+36	+21	+ 9	0	− 4	− 6	−12	−16	−20	−23	−22	−23	−18	
	Dec.	−18	−18	−15	−13	−11	−10	− 9	− 3	+15	+38	+54	+56	+43	+21	+ 3	− 8	− 9	− 8	−11	−15	−17	−18	−18	−18	−15	
	Means	−23	−21	−19	−18	−16	−15	−13	− 6	+11	+33	+49	+58	+50	+35	+19	+ 6	− 2	− 6	−11	−17	−19	−21	−21	−22	−20	
Summer	April	−22	−19	−16	−16	−16	−15	−16	−10	+10	+35	+55	+62	+52	+34	+12	− 6	−13	−12	−12	−15	−17	−18	−18	19	−18	
	May	−19	−15	−15	−15	−15	−15	−13	− 4	+16	+40	+54	+53	+43	+27	+ 9	− 6	−13	−14	−16	−18	−19	−19	−19	−18	−17	
	June	−15	−16	−16	−15	−15	−14	−10	− 5	+ 6	+26	+42	+51	+46	+33	+13	− 3	−12	−15	−15	−14	−14	−14	−15	−15	−14	
	July	−13	−11	−11	−11	−12	−11	− 8	− 2	+11	+27	+37	+42	+35	+27	+12	− 2	−11	−15	−13	−12	−13	−13	−13	14	−13	
	Aug.	−10	− 9	−11	−11	−10	−10	− 8	− 4	+12	+29	+37	+40	+30	+18	+ 5	− 4	−13	−13	−10	−12	−13	−14	−12	−11	− 9	
	Sep.	−19	−15	−15	−12	−13	−13	−14	−10	+13	+41	+63	+63	+47	+21	+ 1	−11	−16	−13	−12	−17	−19	−17	−18	−17	−15	
	Means	−17	−14	−14	−14	−14	−13	−12	− 6	+11	+33	+48	+52	+42	+26	+ 8	− 6	−13	−14	−13	−15	−16	−16	−16	−16	−15	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

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Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1920, from all available days. Vertical Force = ·03000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	028	028	028	027	027	028	**029**	029	029	024	018	012	006	**001**	002	009	015	019	021	024	025	025	026	027	028	021
	Feb.	031	**033**	032	032	032	032	033	031	031	030	024	018	014	010	**005**	007	013	018	024	027	029	030	031	031	032	025
	Mar.	042	042	041	041	041	043	**044**	044	040	035	026	017	**017**	020	024	027	028	030	033	035	037	038	038	040	041	034
	Oct.	055	056	056	057	056	056	**058**	056	052	045	036	**035**	037	037	039	042	045	045	048	049	051	053	055	055	056	049
	Nov.	057	057	057	057	057	058	**059**	057	054	046	041	**036**	037	040	043	045	046	046	049	051	051	051	054	054	056	050
	Dec.	060	059	060	060	061	061	**062**	062	059	050	039	**035**	037	042	049	055	056	053	054	055	056	058	059	060	060	054
	Means	046	046	046	046	046	046	**048**	047	044	038	031	026	**025**	025	027	031	034	035	038	040	042	043	044	045	046	039
Summer	April	047	047	048	047	046	048	**050**	049	041	035	029	**024**	024	029	034	038	039	039	040	041	042	044	045	045	046	040
	May	052	052	052	052	052	054	**056**	056	049	038	030	**025**	027	032	037	041	046	047	046	047	049	051	052	053	054	046
	June	047	046	046	046	046	049	050	**051**	046	039	032	026	**025**	029	033	039	044	044	043	042	043	045	046	046	046	042
	July	047	047	047	047	047	048	**051**	050	048	041	038	036	**034**	036	037	042	044	044	043	043	044	045	046	046	047	044
	Aug.	054	053	053	053	054	055	**058**	056	048	037	033	**031**	037	044	048	052	054	053	049	048	049	050	052	053	053	049
	Sep.	052	053	053	054	054	054	**056**	052	042	031	023	**017**	021	031	041	049	050	047	045	046	047	050	051	053	053	045
	Means	050	050	050	050	050	051	**054**	052	046	037	031	**027**	028	034	038	044	046	046	044	045	046	048	049	049	050	044

Diurnal Inequality of the Vertical Force at Kodaikanal in 1920, deduced from the above table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	+ 7	+ 7	+ 7	+ 6	+ 6	+ 7	+ 8	+ 8	+ 8	+ 3	− 3	− 9	−15	−20	−19	−12	− 6	− 2	0	+ 3	+ 4	+ 4	+ 5	+ 6	+ 7	
	Feb.	+ 6	+ 8	+ 7	+ 7	+ 7	+ 7	+ 8	+ 6	+ 6	+ 5	− 1	− 7	−11	−15	−20	−18	−12	− 7	− 1	+ 2	+ 4	+ 5	+ 6	+ 6	+ 7	
	Mar.	+ 8	+ 8	+ 7	+ 7	+ 7	+ 9	+10	+10	+ 6	+ 1	− 8	−17	−17	−14	−10	− 7	− 6	− 4	− 1	+ 1	+ 3	+ 4	+ 4	+ 6	+ 7	
	Oct.	+ 6	+ 7	+ 7	+ 8	+ 7	+ 7	+ 9	+ 7	+ 3	− 4	−13	−14	−12	−12	−10	− 7	− 4	− 4	− 1	0	+ 2	+ 4	+ 6	+ 6	+ 7	
	Nov.	+ 7	+ 7	+ 7	+ 7	+ 7	+ 8	+ 9	+ 7	+ 4	− 4	− 9	−14	−13	−10	− 7	− 5	− 4	− 4	− 1	+ 1	+ 1	+ 1	+ 4	+ 4	+ 6	
	Dec.	+ 6	+ 5	+ 6	+ 6	+ 7	+ 7	+ 8	+ 8	+ 5	− 4	−15	−19	−17	−12	− 5	+ 1	+ 2	− 1	0	+ 1	+ 2	+ 4	+ 5	+ 6	+ 6	
	Means	+ 7	+ 7	+ 7	+ 7	+ 7	+ 7	+ 9	+ 8	+ 5	− 1	− 8	−13	−14	−14	−12	− 8	− 5	− 4	− 1	+ 1	+ 3	+ 4	+ 5	+ 6	+ 7	
Summer	April	+ 7	+ 7	+ 8	+ 7	+ 6	+ 8	+10	+ 9	+ 1	− 5	−11	−16	−16	−11	− 6	− 2	− 1	− 1	0	+ 1	+ 2	+ 4	+ 5	+ 5	+ 6	
	May	+ 6	+ 6	+ 6	+ 6	+ 6	+ 8	+10	+10	+ 3	− 8	−16	−21	−19	−14	− 9	− 5	0	+ 1	0	+ 1	+ 3	+ 5	+ 6	+ 7	+ 8	
	June	+ 5	+ 4	+ 4	+ 4	+ 4	+ 7	+ 8	+ 9	+ 4	− 3	−10	−16	−17	−13	− 9	− 3	+ 2	+ 2	+ 1	0	+ 1	+ 3	+ 4	+ 4	+ 4	
	July	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4	+ 7	+ 6	+ 4	− 3	− 6	− 8	−10	− 8	− 7	− 2	0	0	− 1	− 1	0	+ 1	+ 2	+ 2	+ 3	
	Aug.	+ 5	+ 4	+ 4	+ 4	+ 5	+ 6	+ 9	+ 7	− 1	−12	−16	−18	−12	− 5	− 1	+ 3	+ 5	+ 4	0	− 1	0	+ 1	+ 3	+ 4	+ 4	
	Sep.	+ 7	+ 8	+ 8	+ 9	+ 9	+ 9	+11	+ 7	− 3	−14	−22	−28	−24	−14	− 4	+ 4	+ 5	+ 2	0	+ 1	+ 2	+ 5	+ 6	+ 8	+ 8	
	Means	+ 6	+ 6	+ 6	+ 6	+ 6	+ 7	+10	+ 8	+ 2	− 7	−13	−17	−16	−10	− 6	0	+ 2	+ 2	0	+ 1	+ 2	+ 4	+ 5	+ 5	+ 6	

NOTE.—When the sign is + the V.F. is greater, and when − it is less than the mean.

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Hourly Means of the Dip at Kodaikanal in 1920, *determined from all available days. Dip = N. 4° + tabular quantity.*

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan.	35·1	35·1	35·1	35·0	35·0	35·1	**35·2**	35·1	35·1	34·5	33·8	33·2	32·6	**32·2**	32·4	33·2	33·8	34·2	34·5	34·7	34·8	34·9	35·0	35·0	35·1	34·4
	Feb.	35·4	**35·6**	35·5	35·5	35·5	35·4	35·5	35·3	35·2	35·0	34·3	33·7	33·3	33·0	**32·6**	32·9	33·5	34·1	34·7	35·0	35·2	35·3	35·4	35·4	35·5	34·7
	Mar.	36·5	36·5	36·4	36·4	36·4	36·6	**36·6**	36·6	36·1	35·4	34·4	**33·5**	33·6	34·0	34·6	34·9	35·0	35·2	35·5	35·8	36·0	36 1	36·1	36·3	36·4	35·6
	Oct.	37·4	37·5	37·5	37·6	37·5	37·5	**37·7**	37·4	36·9	36·1	35·1	**35 0**	35·2	35·4	35·7	36·1	36·4	36·4	36·7	36·9	37·1	37·3	37·4	37·4	37·5	36·7
	Nov.	37·6	37·6	37·5	37·5	37·5	37·6	**37·7**	37·4	37·0	36·2	35·6	**35·2**	35·4	35·7	36·1	36·4	36·5	36·5	36·8	37·0	37·0	37·1	37·3	37·3	37·5	36·8
	Dec.	37·8	37·7	37·8	37·7	37·8	37·8	**37·9**	37·9	37·5	36·5	35·4	**35·0**	35·3	35·9	36·6	37·3	37·4	37·1	37·2	37·3	37·4	37·6	37·7	37·8	37·8	37·1
	Means	36·6	36·7	36·6	36·6	36·6	36·7	**36·8**	36·6	36·3	35·6	34·8	34·3	**34·2**	34·4	34·7	35·1	35·4	35·6	35·9	36·1	36·3	36·4	36·5	36·5	36·6	35·9
Summer.	April	36·9	36·9	37·0	36·9	36·8	37·0	**37·2**	37·0	36·2	35·4	34·8	**34·2**	34·3	34·9	35·5	36·0	36·1	36·1	36·2	36·3	36·5	36·6	36·7	36·7	36·8	36·2
	May	37·3	37·2	37·2	37·2	37·2	37·4	**37·6**	37·5	36·8	35·6	34·8	**34·3**	34·6	35·1	35·7	36·2	36·7	36·8	36·7	36·8	37·0	37·2	37·3	37·4	37·4	36·6
	June	36·7	36·6	36·6	36·6	36·6	36·9	36·9	**37·0**	36·5	35·7	34·9	34·3	**34·3**	34·7	35·2	35·9	36·4	36·4	36·3	36·2	36·3	36·5	36·6	36·6	36·6	36·1
	July	36·7	36·6	36·6	36·6	36·7	36·7	**37·0**	36·9	36·6	35·8	35·5	35·3	**35·1**	35·4	35·6	36·1	36·4	36·4	36·3	36·3	36·4	36·5	36·6	36·6	36·7	36·3
	Aug.	37·3	37·2	37·2	37·2	37·3	37·4	**37·6**	37·4	36·6	35·4	35·0	**34·8**	35·4	36·2	36·6	37·0	37·3	37·2	36·8	36·7	36·8	36·9	37·1	37·2	37·2	36·7
	Sep.	37·2	37·2	37·2	37·3	37·3	37·3	**37·5**	37·1	36·0	34·8	34·0	**33·4**	33·9	35·0	36·0	36·8	37·0	36·7	36·5	36·6	36·7	37·0	37·1	37·3	37·2	36·4
	Means	37·0	37·0	37·0	37·0	37·0	37·1	**37·3**	37·2	36·5	35·5	34·8	**34·4**	34·6	35·2	35·8	36·3	36·7	36·6	36·5	36·5	36·6	36·8	36·9	37·0	37·0	36·4

Diurnal Inequality of the Dip at Kodaikanal in 1920, *deduced from the above table.*

Winter.	Jan.	+0′7	+0′7	+0′7	+0′6	+0′6	+0′7	+0′8	+0′7	+0′7	+0′1	−0′6	−1′2	−1′8	−2′2	−2′0	−1′2	−0′6	−0′2	+0′1	+0′3	+0′4	+0′5	+0′6	+0′6	+0′7	
	Feb.	+0·7	+0·9	+0·8	+0·8	+0·8	+0·7	+0·8	+0·6	+0·5	+0·3	−0·4	−1·0	−1·4	−1·7	−2·1	−1·8	−1·2	−0·6	0·0	+0·3	+0·5	+0·6	+0·7	+0·7	+0·8	
	Mar.	+0·9	+0·9	+0·8	+0·8	+0·8	+1·0	+1·0	+1·0	+0·5	−0·2	−1·2	−2·1	−2·0	−1·6	−1·0	−0·7	−0·6	−0·4	−0·1	+0·2	+0·4	+0·5	+0·5	+0·7	+0·8	
	Oct.	+0·7	+0·8	+0 8	+0·9	+0·8	+0·8	+1·0	+0·7	+0·2	−0·6	−1·6	−1·7	−1·5	−1·3	−1·0	−0·6	−0·3	−0·3	0·0	+0·2	+0·4	+0·6	+0·7	+0·7	+0·8	
	Nov.	+0·8	+0·8	+0·7	+0·7	+0·7	+0·8	+0·9	+0·6	+0·2	−0·6	−1·2	−1·6	−1·4	−1·1	−0·7	−0·4	−0·3	−0·3	0·0	+0·2	+0·2	+0·3	+0·5	+0·5	+0·7	
	Dec.	+0·7	+0·6	+0·7	+0·6	+0·7	+0·7	+0·8	+0·8	+0·4	−0·6	−1·7	−2·1	−1·8	−1·2	−0·5	+0·2	+0·3	0·0	+0·1	+0·2	+0·3	+0·5	+0·6	+0·7	+0·7	
	Means	+0·7	+0·8	+0·7	+0·7	+0·7	+0·8	+0·9	+0·7	+0·4	−0·3	−1·1	−1·6	−1·7	−1·5	−1·2	−0·8	−0·5	−0·3	0·0	+0·2	+0·4	+0·5	+0·6	+0·6	+0·7	
Summer.	April	+0·7	+0·7	+0·8	+0·7	+0·6	+0·8	+1·0	+0·8	0·0	−0·8	−1·4	−2·0	−1·9	−1·3	−0·7	−0·2	−0·1	−0·1	0·0	+0·1	+0·3	+0·4	+0·5	+0·5	+0·6	
	May	+0·7	+0·6	+0·6	+0·6	+0·6	+0·8	+1·0	+0·9	+0·2	−1·0	−1·8	−2·3	−2·0	−1·5	−0·9	−0·4	+0·1	+0·2	+0·1	+0·2	+0·4	+0·6	+0·7	+0·8	+0·8	
	June	+0·6	+0·5	+0·5	+0·5	+0·5	+0·8	+0·8	+0·9	+0·4	−0·4	−1·2	−1·8	−1·8	−1·4	−0·9	−0·2	+0·3	+0·3	+0·2	+0·1	+0·2	+0·4	+0·5	+0·5	+0·5	
	July	+0·4	+0·3	+0 3	+0·3	+0·4	+0·4	+0·7	+0·6	+0·3	−0·5	−0·8	−1·0	−1·2	−0·9	−0·7	−0·2	+0·1	+0·1	0·0	0·0	+0·1	+0·2	+0·3	+0·3	+0·4	
	Aug.	+0·6	+0·5	+0·5	+0·5	+0·6	+0·7	+0·9	+0·7	−0·1	−1·3	−1·7	−1·9	−1·3	−0·5	−0·1	+0·3	+0·6	+0·5	+0·1	0·0	+0·1	+0·2	+0·4	+0·5	+0·5	
	Sep.	+0·8	+0·8	+0·8	+0·9	+0·9	+0·9	+1·1	+0·7	−0·4	−1·6	−2·4	−3·0	−2·5	−1·4	−0·4	+0·4	+0·6	+0·3	+0·1	+0·2	+0·3	+0·6	+0·7	+0·9	+0·8	
	Means	+0·6	+0·6	+0·6	+0·6	+0·6	+0·7	+0·9	+0·8	+0·1	−0·9	−1·6	−2·0	−1·8	−1·2	−0·6	−0·1	+0·3	+0·2	+0·1	+0·1	+0·2	+0·4	+0·5	+0·6	+0·6	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

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THE COMPUTING OFFICE.

By Dr. J. de GRAAFF HUNTER, M. A., Sc. D., F. Inst. P.

PERSONNEL.

Class I Officer.

Dr. J. de Graaff Hunter, M. A., Sc. D., F. Inst. P., in charge.

Class II Officer.

Mr. Hanuman Prasad.

Upper Subordinate Service.

Mr. Sarat Kumar Mukerji.

Computing Office.

Rai Sahib Ishan Chandra Deva, B. A., Head Computer, 10 Senior and 5 Junior Computers; 9 Computers from field parties worked for a portion of the year.

Printing Office.

1 Assistant Supervisor, 2 Clerks, 25 Compositors, 6 Distributers, 3 Pressmen, 1 Stereotyper, 3 Machine Printers, 7 Inkmen, 1 Roller moulder and 13 Book-binders.

Workshop.

1 Head Artificer, 21 Carpenters, and fitters.

Solar Photography.

1 Assistant Solar Photographer.

Computations.—The following computations were carried out during the year under review :—

(*a*) Graticules of maps for Sir Aurel Stein and No. 2 Drawing office.

(*b*) Longitude of Dehra Dūn by wireless telegraphy.

(*c*) Plumb-line deflections in Turkistān referred to Helmert's spheroid.

(*d*) Computations for Auxiliary Tables, Part III, 5th Edition.

(*e*) Bouguer and Hayford corrections for pendulum stations in Turkistān.

(*f*) Meteorological computations.

(*g*) Heights of gravity stations in Turkistān.

(*h*) Re-modelling of computation forms.

(*i*) Re-grinding of a figure in the Burma Coast Series.

(*j*) Adjustment of new stations fixed by Mr. J. Bond in Assam after the Assam Earthquake of 1897.

Adjustments.—(*a*) Heights of Khāsi and Jaintiā Hills Series and of Mönghsat and Mawkmai Series have been adjusted.

(*b*) Kashmīr Series, Indo-Russian connection, Mönghsat and Mawkmai Series were completed this year.

(*c*) Pendent portion of the Kashmīr Series has been adjusted.

(*d*) Kāgān, Changchenmo, Rupshu, Bārā Lācha and Upper Indus Secondary Series and minor triangulation falling in degree sheets, 39A and E, have also been adjusted this year.

Investigation.—Some computations have been carried out in order to investigate (*a*) the formulæ for barometric heights, (*b*) the personal equation between Dr. Hunter's and Major Mason's star observations, (*c*) the pressure and temperature at Kinchinjunga and K^2 and (*d*) the height of Mount Everest.

Triangulation Pamphlets.—Final corrections were applied to the latitude, longitude, azimuth, log side and heights of stations and intersected points of triangulation falling in 70 degree sheets in Burma, N.W. Frontier and transfrontier regions, 120 pamphlets were compiled, 104 compared and 87 sent to press; of these latter 51 copies were published during the year. Besides these, fair copies of 52 pamphlets were made.

Levelling.—As mentioned in last year's report, Levelling Pamphlet 54 has been reprinted. An addendum to Levelling Pamphlet 44 and a large number of slips containing records of the work of season 1919-20 have been printed for incorporation in Pamphlets 38, 39, 47, 53, 63, 78, 79 and 83.

Revision.—(*a*) The following forms have been revised:—

Trian: Nos. 16 to 21, Topo: Nos. 7 to 9, 12 to 15 and 23 to 25, the last three being new forms, also Trav: Nos. 8 to 10.

(*b*) Auxiliary Tables, 5th Edition.—(1) Part I reprinted, (2) Part II reprinted with a new table (23 Math. 6-figure logarithms of numbers), (3) Part III, 23 tables have been prepared.

Requisitions.—250 requisitions for data were received from departmental and non-departmental officials. In some cases these requisitions were met by the supply of printed publications, in others it was necessary to extract the required information from manuscript records. On requisitions from the Siam State and Superintendent, Eastern Circle, copies of triangulation data in Burma were made and supplied.

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Research.—(1) **Wireless Longitude Observation, January—March 1921.**

A Marconi multi-valve amplifier and detector, type 55 A, was lent by the Deputy Director, Army Signalling, and Lieutenant C. E. Sketch, 3rd Wireless Squadron with 4 British other ranks brought the apparatus to Dehra Dūn and explained its use. Paris signals were picked up on the third day, and after that on most mornings of observations. Nauen (Berlin), Caernarvon and Tokyo were frequently heard. At the outset atmospherics were troublesome. Two aerials were tried, one 72 feet high in the Survey compound among trees, and the other 100 feet high on the *maidān* in the open. The latter gave somewhat louder signals, but atmospherics were not reduced, as had been hoped. A still greater disturbance was caused by the working of some Central Asian station, on the same wave length as Paris. Quetta interfered several times, until the Director of Wireless issued orders that there should be no signalling of messages at the time of the time signals.

The Paris signals are of two kinds (1) ordinary, in which the precise times 11-45, 11-47, 11-49 (night) are indicated by the beginning of a bar, after suitable warning signals, and (2) scientific, in which 300 dots equally spaced are sent out in about 293 seconds, beginning shortly after 11-00 (night, Greenwich time). The precise times, to 0·01 second, of first and last dots, are signalled after the ordinary time signals are finished. These dots are heard in a double telephone receiver, in which the clock beats are also made audible. The dots gradually overtake the clock beats and it is only necessary to note the moment at which the two coincide, as they do 5 times in a set.

Coincidences were successfully noted on five mornings by Dr. Hunter, and on two mornings by Major Mason. The transits of time stars were observed before and after the wireless signals. The results obtained cannot at present be cleared of personal equation in time determination, as the Dehra transit instrument is not fitted with an "impersonal micrometer".

The following are the values of the difference of longitude from Greenwich that have been determined:—

5 hours 12 minutes 11·220 seconds, by Dr. Hunter
5 hours 12 minutes 11·383 seconds, by Major Mason } by wireless in 1921.

5 hours 12 minutes 11·267 seconds, by Sir Sidney Burrard, and Sir Gerald Lenox-Conyngham in 1894-96, by ordinary telegraph by land and sea.

The experiments have shewn the feasibility of the method for determining the longitude of any Indian station, by direct reference to the Greenwich meridian. It is also clear that it is necessary to fit an "impersonal micrometer" to transit instruments used for this work.

(2) **Investigation of atmospheric refraction.**

It was noticed in 1913 (*vide* Survey of India Professional Paper No. 14, chapter iv) that the diurnal change in refraction was in some cases very closely a linear function of the temperature. In two cases examined, the greater diurnal change occurred on the shorter ray. This was considered surprising and no explanation was forthcoming. In relation to this question, simultaneous observations of barometers at Mussoorie and Dehra were made at several hours of the day for 23 days. The difference of height of the two barometers was deduced by formula from these readings and was found to differ from the spirit-levelled difference of height by amounts which varied at the different hours as follows:—

Hour	8	10	12	14	16
Barometric height *minus* Spirit-level height in feet	−65	−19	+7	−4	−17

In endeavouring (in 1921) to explain the diurnal change in refraction, an attempt was made to work out the relation between temperature variation of the air at various heights with that at ground level. It appears that the variation may be split up into two parts (1) conduction effect, (2) radiation effect. The first effect diminishes rapidly with height, and at 100 metres will not exceed 1 per cent of its value near the ground. The second effect, probably depending a good deal on the state of humidity, should be much the same at all heights dealt with.

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As regards the refraction, the second effect has but little influence; for, the main determining factor is the gradient of temperature with height. The conduction effect is very much greater. Its effect is easily computed for a ray of light which soon passes out of the conduction region. If α is the angle of elevation of the ray and $\delta\tau_c$ is the portion of the variation of temperature from its maximum value which is due to conduction, the change in refraction resulting is given by applying $\mu \sin \phi = \mu' \sin \phi'$ at the ground level and at a height of (say) 100 metres. Then $\delta\mu \propto \delta\rho \propto \delta\tau$ and the refraction $= A\delta\tau_c \cot \alpha$ where A is a physical constant. It is found in cases dealt with that if $\delta\tau_c$ is taken equal to $\frac{5}{6}\delta\tau$, where $\delta\tau$ is the defect of temperature near surface from maximum, the observed changes in refraction are closely explained.

It appears that the radiation portion $\delta\tau_r$ of the temperature variation is of the form $a\delta\tau + b\frac{d\tau}{dt}$, t being the time. In the barometric formulæ it is necessary to get the mean value of $\frac{1}{\tau} = \left(\frac{1}{\tau}\right)_m$. Usual formulæ have put this equal to $\frac{2}{\tau_1+\tau_2}$ where τ_1, τ_2 are the temperatures observed at both ends. This value of $\left(\frac{1}{\tau}\right)_m$ is not likely to be correct when there is a much larger variation of temperature near the surface than in the higher layers of air. In fact it is clear that much better results will be obtained if $\delta\tau_c$ is applied to the observed temperatures. The barometer results uphold this view and the observations at 8, 10, 12 hours fall nearly on a straight line when plotted against temperature observed near the ground. Observations at 14 and 16 hours fall distinctly to one side of this line. The explanation seems to be in the term $\frac{d\tau}{dt}$; in fact an empirical expression $a'\delta\tau + b'\frac{d\tau}{dt}$ can be found which closely represents the tabular quantities given above. This also leads to the partition of temperature variation into two parts almost in the proportion of 5 : 1 due to conduction and radiation respectively. What has been said about conduction effect is primarily applicable to a station in a plain. On a hill top convection will cause a re-adjustment. On this account the diurnal variation of refraction from a hill station is less than it would be at a plateau station. Observation has shown this to be the case.

According to this reasoning the following seems to be probable.—

(1) The line representing temperature of air plotted against height is practically straight at about 14 hours right to within a few feet from ground.

(2) At earlier hours in the day, the general slope of this line is not much changed; but it is displaced as a whole to a smaller temperature and its termination near (say within 100 metres of) the ground is now curved towards the direction of lower temperature, the curvature increasing as the earth is approached.

It now appears possible to represent the refraction of a ray which does not lie close to the ground, at any time in the form, $kc + fA\left(\tau_m - \tau\right)\cot\alpha$ in which c is the length of the ray in seconds of arc, k is a factor depending on temperature and pressure of the air at the observing station, α is the angle of elevation of the ray, τ is the temperature and τ_m its maximum value, A is a constant and f is a factor so far found to be about $\frac{5}{6}$.

The observations to determine the height of Mount Everest have been partially dealt with, using this formula and this has resulted in improved accordance in the height obtained by each observation.

(3) Adjustment of Triangulation networks.

The simultaneous adjustment of a network of triangulation to surrounding triangulation according to the general method of least squares involves the solution of such a great number of simultaneous linear equations as to be quite impracticable. To solve, say, 20 simultaneous equations is a work which will occupy a computer the best part of a week; and when it is remembered that the labour increases as the cube of the number of equations it will be seen that to solve, say, 100 simultaneous equations will occupy some two years making no allowance for mistakes. Now, in a network the errors to all the angles enter the equations simultaneously, so that quite a small network would give rise to an enormous amount of labour. By a little generalisation the problem may be solved in a way which leads to results wholly consistent *inter se* and departs but little from the adjustment which is most probable.

First consider the case of a network of equilateral triangles all of the same size, with angles all equally carefully measured and so all having the same probable error. Consider next that the size of these triangles is small compared with the area dealt with. Both of these

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modifications lead to a case not seriously different from the actual case; for, it is always the object of the triangulator to select triangles nearly equilateral. We are led then to the case of a uniform "plate" which has to be strained to fulfil certain given conditions of closure.

If we take ξ and η to be the movement of any point parallel to axes Ox, Oy and introduce the condition that at any point the scale value and azimuth is changed by the same amount for all azimuths, the following equation must hold

$$\frac{\delta^2 V}{\delta x^2}+\frac{\delta^2 V}{\delta y^2}=0 \quad \ldots \quad \ldots \quad \ldots \quad (1),$$ where V is put equal to ξ or η.

Also $$\frac{\delta\xi}{\delta x}=\frac{\delta\eta}{\delta y} \text{ and } \frac{\delta\xi}{\delta y}=-\frac{\delta\eta}{\delta x} \quad \ldots \quad (2).$$ It also follows that the change is in azimuth δA and in scale value ϵ (*i.e.* new scale: old scale $=1+\epsilon$: 1), that δA and ϵ are of form $\frac{\delta\xi}{\delta x}$ and $\frac{\delta\eta}{\delta y}$. These values are applicable to a point. To find the effect on a line they have to be integrated along that line, which is easily done. The problem is accordingly reduced to the solution of (1) subject to the given closing conditions.

The solution of (1) is of form $\Sigma A_n r^n \cos(n\theta+\delta_n)$. By taking enough terms it is possible to satisfy any number of conditions: whereby suitable values of A_n and δ_n are obtained. It is to be noted here that the number of simultaneous linear equations for solution is equal to the number of conditions to be satisfied.

A variety of solutions can be found: but it is clear that the most probable one is that which involves the smallest values of n and this solution is the actual most probable solution of the hypothetical case.

The solution is simple when there are only a few conditions to be satisfied—say the closure on a single side, which involves the solution of only four simultaneous equations.

After the equations have been solved it is necessary to compute values of ξ, η, at sufficient numbers of points to draw contours of equal value; and this is the heaviest part of the work if large values of n occur. If this is done on tracing cloth, it can be superposed on the chart of triangulation and the correction at any point may be immediately read off.

To visualise the process we introduce the idea of change of azimuth and scale *at a point*, and so imagine in actual triangulation that the rays joining the points become slightly curved. If we imagine a "plate" of uniform strength with the triangulation marked out on it, then by straining the plate (within its elastic limits, and without buckling it) to fit the closures, all the triangulation on it would be deformed in the way described. It is clear from this that the actual case would be represented by the distortion of the plate of strength varying from point to point which enables us to estimate how far the solution departs from that actually most probable. The method has been devised primarily to deal with adjustment of minor triangulation.

Printing Section.

The following were printed in the course of the year:—

Professional Papers Nos. 18 and 19 (print and reprint), Auxiliary Tables Parts I and II (reprint) and 19 tables of Part III (set up and partly printed), Catalogue of Library Books, Vol. XV (1919-20) of the Records of the Survey of India (set up), 51 Triangulation pamphlets, Levelling pamphlets—No. 54 (reprint) and No. 44 (addendum) and slips for Levelling pamphlets 38, 39, 47, 53, 63, 78, 79 and 83 with additional pages containing new work.

In the Book-binding Section, the work dealt with comprised 800 copies of Triangulation pamphlets, 150 copies of Levelling pamphlets, 350 copies of Professional Paper No. 18, 450 copies of Professional Paper No. 19 (including 100 copies reprint), 100 copies of Auxiliary Tables, Part I, 5th Edition (reprint), 250 copies of Catalogue of Library Books and 3,500 copies of miscellaneous publications including angle books and Library books.

The binding of 350 copies of the Records Volume XIV was also completed.

Workshop.

During the year the following work was done:—

245 zinc tablets and 200 wooden pegs were made for No. 17 Party and 1580 rollers for No. 2 Drawing Office and Forest Map Office. Repairs to 17 theodolites of the Sind-Sāgar Party and No. 22 (Riverain) Party and to various instruments of No. 17 Party were carried out. One godown was constructed under the supervision of this section, also 32 doors and windows for the new godowns. Minor electrical installation was carried out in various sections, and other

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miscellaneous work done including the construction of 313 packing cases and 50 *chongas* as well as racks, almirahs, stools, cabinets, ladders, tables, fire bucket stands etc. required by various offices.

Observatories.

Seismography and Meteorology:—(1) The Omori seismograph was in operation throughout the year and the usual daily meteorological observations were made. (2) The Photo-helio observatory continued its work as in past years.

The following statements show the earthquakes recorded and the number of days on which solar photographs were taken :—

1. *Statement of earthquakes recorded during the year 1920-21.*

No.	Month and Date.	Time of beginning (corrected).		Duration.	Distance of Epicentre.		Remarks. Intensity &c.
		Dehra.	Simla (from W.R.*)		Dehra.	Simla (from W.R.*)	
		hrs mts	*hrs mts*	*m*	*miles*	*miles*	
1	21-10-20	13 51½	13 52	72	4,000	4,000	Moderate.
2	17-12-20	17 43	17 30	192	1,000	1,500	Violent.
3	26-12-20	17 9½	17 9	43	1,000	1,500	Slight.
4	17- 2-21	7 58½	7 57	1½	120	local	,,
5	21- 2-21	7 34	7 35	15	150	300	,,
6	28- 2-21	0 16	0 15	120	2,000	8,000	Moderate.
7	31- 3-21	16 1	16 1	28	1,400	1,000	,,
8	1- 4-21	9 47½	...	18	2,500	...	Great intensity.
9	20- 5-21	6 15	6 15	21	375	300	Moderate.
10	26- 7-21	0 56	...	3	100	...	Slight.
11	26- 7-21	2 50	2 47	4	300	1,000	,,
12	2- 9-21	17 46	17 47	2	80	local	,,

* W. R. indicates Daily Weather Report published at Simla.

2. *Statement showing the number of days on which solar photographs were taken during the year 1920-21.*

Month.	No. of days.	8″ Negatives.		12″ Negatives.		No. of days on which sun was invisible.	Month.	No. of days.	8″ Negatives.		12″ Negatives.		No. of days on which sun was invisible.
		Good.	Bad.	Good.	Bad.				Good.	Bad.	Good.	Bad.	
October ...	31	57	4	...	...	...	April ...	30	48	6	1	1	...
November ...	29	54	3	1	1	1	May ...	28	38	8	.	...	3
December ...	31	56	9	...	..	...	June ...	28	28	4	...	...	2
January ...	28	45	6	...	...	3	July ...	21	31	6	...	...	10
February ...	27	49	4	1	...	1	August ...	16	23	2	..	...	15
March ...	31	51	6	1	1	...	September...	20	33	6	...	...	10
							Total ...	320	513	64	4	3	45

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PART III.—SPECIAL REPORTS.

HIGH CLIMBS IN THE HIMALAYA PRIOR TO THE EVEREST EXPEDITION.

By Major Kenneth Mason, M.C., R.E.

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At a time when the Alpine Club, Royal Geographical Society, and Survey of India are combining in an effort to reach the earth's highest summit, it is interesting to review briefly the most prominent mountaineering achievements in the Himālaya. With a northern barrier of stupendous ranges containing the highest peaks of the earth, it is not surprising that for more than eighty years, the mountaineering altitude record has lain in this borderland. It is not proposed to deal with ascents outside this region, nor with expeditions that do not involve high mountain climbs. It may however be mentioned that in other continents, Aconcagua alone attains an altitude of 23,000 feet, and its summit has been reached.

The first recorded ascent to this altitude is typical of the lack of interest in alpine craft, which has almost invariably been exhibited by the vast majority of Englishmen in India; and, incidentally, this climb is one of the very few records, the authority of which has never been assailed. About 1860, an Indian khalasi of the Great Trigonometrical Survey, carried a pole to and fixed it at the summit of Shilla in Spiti. The height was unknown till the observations were made and the results computed; no interest was then aroused, the man's name was forgotten, and the record was buried in a large volume of figures.

It was not till about 1906, nearly fifty years afterwards, that Dr. T. G. Longstaff, on a visit to India, interesting himself in the Survey records, discovered that the Shilla khalasi had held the world's altitude record, 23,050 feet, for some years.

During the surveys of Kāngra, Kumaun, Kashmīr and Ladākh from 1850 to 1865, no less than 37 ascents to over 20,000 feet, including 5 to above 21,000, were made by the Survey of India employés and have been proved by careful trigonometrical observations; if the plane-table fixings of the detailed survey are included, these numbers must be vastly increased. Of all of them, the most interesting which has led to much controversy, was the casual statement by Mr. W.H. Johnson in the report of his journey to Khotan in 1865, that he had climbed the mountain "E61", whose height had previously been determined by triangulation to be 23,890 feet. Mr. Johnson himself laid no claim to an altitude record, probably because no one was particularly interested in such matters in those days. Nevertheless it is now practically certain that owing to the point being incorrectly plotted on his plane-table, it was not "E61" but either Zokputaran, Pk 2/61A, (22,639) or Cholpanglik, Pk 8/52M, (23,309) that was climbed. In any case, either climb, coupled with his other achievements, entitles Johnson to a foremost place among the mountaineers of his day.

In 1883, Mr. W.W. Graham, assisted by Swiss guides, made some notable ascents in Sikkim. He claimed to have reached a point within 50 feet of the summit of Kabru, Pk 16/78A, (24,002) and to have established a world's altitude record. Though supported by Freshfield, doubt has often been thrown on the ascent, and the latest opinion among experts, including the president of the Alpine Club and Harold Raeburn, the leader of Everest's mountaineering party, is that Graham was mistaken and that the peak he climbed was the lower "Forked Peak".

There are no further records or claims to 23,000 feet until Dr. H. Workman reported that he reached a point estimated by him at 23,394 feet on a peak in the Chogo Lungma region in 1903. Later, in 1906, Mrs. Bullock Workman claimed to have reached the summit of "Pinnacle Peak", (Pk 6/52B) in the Nun Kun district. She contended that the height of the peak was 23,300 feet, and that the triangulated survey height, 22,810, was inaccurate. The peak however has been refixed since then, and the old height has been found to be correct within a very few feet. Nevertheless this climb of Mrs. Bullock Workman is, it is believed, an altitude record for ladies.

In 1905, Dr. T. G. Longstaff came to India and we get definite records that are unchallenged. In that year, with the assistance of the two Brocherels from Switzerland, he

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attempted the ascent of Gurla Mandhata (Pk 7/62F), 25,355. Of all climbs in the Himālaya, this one of Longstaff stands out as the supreme exhibition of human endurance. From a camp at 20,000 feet, the party reached a height of about 23,000 feet on the western *arête* of the mountain. At this point an avalanche swept them away to a glacier some 1,000 feet below; by keeping their wits they succeeded in extricating themselves from the snow and camped in the shelter of some rocks near the glacier.

This they ascended the following day, and reached a point above 23,000 feet, where they were forced to spend their fourth night in a hole dug in the snow. On the fifth day they made their final effort, and though Longstaff has never claimed to have reached 24,000 feet, most competent critics credit him with having reached this altitude.

In 1907, Longstaff made another expedition to Garhwāl, and with a Swiss guide and Gurkha orderly reached the summit of Trisūl (Pk 117/53N), 23,360 feet. The climbing of nearly 6,000 feet in 10½ hours, on the last day at this altitude, was the notable feature of this climb.

During the same year two Norwegians, Rubensen and Monrad Aas, reached the summit of Kabru, 24,002 (Pk 16/78 A). For twelve days they struggled through ice and snow at altitudes over 20,000 feet, a single icefall, 1,500 feet in height, taking them five days to negotiate.

The present height record* was attained by the Duke of the Abruzzi in 1909. After setting out with the object of climbing K^2, the second highest mountain in the world, and after reconnoitring all sides of it in vain for practicable routes to its summit, he decided to attack "Bride Peak" (Pk 25/52A), on the south side of the Baltoro glacier. Nine days were spent over 20,000 feet, and a final altitude of 24,583 (from hypsometric readings) was reached. The party was eventually stopped by foul weather and the summit which had been fixed by the Survey of India at 25,510 was not attained.

Mr. C. F. Meade's expeditions in 1910, 1912 and 1913, with a Swiss guide, are particularly interesting, for they illustrate the results that may be obtained by perseverance in the attempt to conquer a particular peak. Meade selected Kāmet, (Pk 49/53N), the height of which was known to be 25,447 feet. In his last expedition he reached a saddle to its north, pitched his camp there and ascended about 100 feet higher. The height of this camp, estimated by him at 23,000 feet, has since been fixed by the Survey of India as 23,500, and is the record altitude* at which human beings have passed a night. The actual height reached was about 23,600, but the party was forced back by exhaustion, powdery snow and a powerful sun.

Lieut. Slingsby about the same time, reached a point about 23,350 on the other side of Kāmet, and Dr. Kellas and Major Morshead last year (1920) followed Meade's route and reached his camping ground on the Kāmet saddle, where however their coolies refused to take their camp. Among other climbs of Dr. Kellas, may be mentioned that on Pauhunri in Sikkim, 23,186.

The list above embraces all the recorded climbs over 23,000 feet in the Himālaya, and nothing has been said of the many lesser climbs which have been made and recorded in the annals of the Alpine Club. References to these are often extremely scrappy and difficult to follow, for maps in India have not been made with a view to assist in the identification of minor peaks, the vast majority of which are unnamed and unnumbered. Allusions to "Broad Peaks", "Pointed Peaks", "Snowy Peaks", &c., make the task of investigation an impossible one, as such names are not entered on our maps. Nevertheless there are undoubtedly many ascents of the highest climbing order that have been made in this country by members of the Alpine Club.

This short summary would be incomplete and misleading, unless mentions were made of a few failures. Everest, first and foremost, has never been attempted. But K2 and Kinchinjunga, the next on the list of high peaks, have both been visited. Several expeditions under competent leadership have visited them, and the conclusion has been reached that neither presents a feasible route sufficiently easy to negotiate at that high altitude.

Glaciers and mountains have claimed their victims in the Himālaya as in other parts of the world; but with the exception of an insignificant number of accidents due to hidden crevasses, which are always avoidable with proper precautions, and the fatal but unforeseen avalanche on Nanga Parbat, resulting in the death of Mummery, the remaining fatalities have befallen sportsmen generally in search of game. These have either not realized the risks or taken no precautions. In the Himālaya, as in the Alps, far more accidents are caused by ignorance of the art among amateurs than by acts of God.

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* These records have since been beaten by the Everest expedition 1922.

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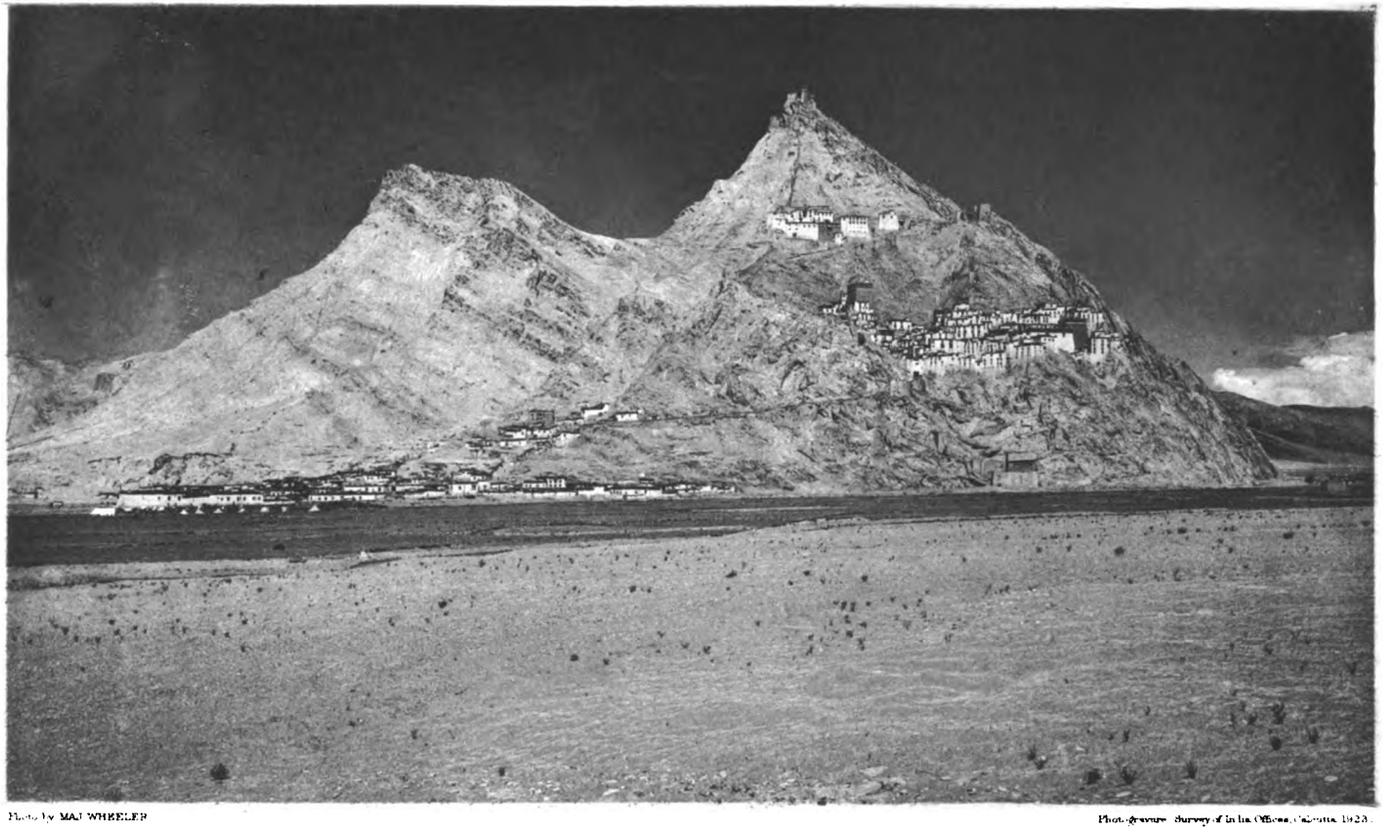

Photo by MAJ WHEELER

Photo-gravure Survey of India Offices, Calcutta, 1923.

SHEKAR VILLAGE AND MONASTERY

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REPORT ON THE OPERATIONS OF THE MT. EVEREST SURVEY DETACHMENT, 1921.

I.—Narrative Report.

By Major H. T. Morshead, D. S. O., R. E.

Introduction.

Towards the end of December 1920, news was received that Mr. C. A. Bell, C. M. G., C. I. E., I. C. S., then in Lhāsa on a special mission, had succeeded in obtaining the consent of the Tibetan Government to the despatch of an Expedition to Mount Everest. Preparations were at once put in hand in England by a joint committee of the Alpine Club and the Royal Geographical Society, and an expedition was organised under the leadership of Lt.-Col. C. K. Howard Bury, D. S. O., an officer who had only recently returned from India, whither he had gone at his own expense, with the object of investigating the possibilities of such a scheme.

The other members, selected by the Mt. Everest Committee to form the expedition, were:—

H. Raeburn, Esq. } Mountaineering
Dr. A. M. Kellas, D. Sc., Ph. D. } Experts.
G. L. Mallory, Esq. } Climbers.
G. H. Bullock, Esq. }

Dr. A. F. R. Wollaston, D. S. C., M. A., M. B., Surgeon and Naturalist.

In addition, the Indian Government agreed to the deputation of a small survey detachment, and of an officer of the Geological Survey (Dr. A. M. Heron, D. Sc., M. A.). The expedition, with a large supply of stores and equipment, assembled in Darjeeling early in May.

The composition of the Survey Detachment selected to accompany the expedition is given below:—

Class I Officers.

Major H. T. Morshead, D.S.O., R. E., in charge.
Bt.-Major E. O. Wheeler, M. C., R. E.

Upper Subordinate Service.

Mr. Lalbir Singh.

Lower Subordinate Service.

1st Class Surveyor Gujjar Singh.
Inter „ „ Torabāz Khan.
3rd Division Photographer Abdul Jalil.

Menial Establishment.

16 Khalasis, etc.

The detachment was placed under the administrative control of the Superintendent of the Trigonometrical Survey.

The tasks allotted to the detachment were:—

(1) A general survey of the whole unmapped area covered by the expedition, on the scale of 4 miles = 1 inch.

(2) A detailed survey of the immediate environs of Mt. Everest on the scale of 1 inch to 1 mile.

(3) A complete revision of the existing ¼-inch map of Sikkim (sheet 78 A).

The survey operations were to be confined as far as possible to the beaten track followed by the expedition. In deference to Tibetan susceptibilities, the survey operations were to be confined as far as possible to the beaten track followed by the expedition. Col. Bury's plans contemplated an outward northerly journey *viâ* Shekar and Tingri to the western flank of Mt. Everest, whence the reconnaissance of the mountain was to be carried out from west to east, parallel to the northern frontier of Nepāl. This rendered feasible the mapping of the whole unknown area between the southern watershed of the Tsangpo river (the so-called Ladākh Range) on the north, and the main Himālaya Range (the Nepāl-Tibet frontier) on the south, as far west as Long. 85° 30′.

For the purpose of the detailed survey, it was arranged that Major Wheeler should make a thorough test of the Canadian pattern of photo-survey apparatus, of which he had had previous experience in Canada. This method of survey is specially adapted for use in high

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mountain regions. Fortunately, the experimental outfit, which had recently been ordered from England, was delivered just in time to accompany the expedition. Major Wheeler's report on his season's work will be found on page 117.

With a view to carrying out the revision survey of Sikkim while awaiting the arrival of the members of the expedition from England, the Survey detachment was authorised to assemble at Darjeeling early in April—six weeks before the date fixed for the start of the expedition. The surveyors were provided with special "combined" blue-prints of the latest (1921) edition of the map; these were pinned to the plane-tables on the top of sheets previously mounted and prepared for use in the Mt. Everest area, so that at any moment when required to advance each surveyor had merely to strip the top sheet of paper from his board.

Narrative Report.

After completing the necessary arrangements with Col. Bury, I left Darjeeling on 13th May, intending to join the remainder of the expedition at Kampa Dzong, after inspecting the work of the three surveyors in Sikkim. Continuous rain however, rendered the latter task impossible; the road was moreover blocked in several places by severe landslips, so that I only reached Kampa Dzong on 28th.

The remainder of the expedition, which had left Darjeeling in two parties on 18th and 19th May, had been delayed in the Chumbi Valley owing to the breakdown of the 100 transport mules lent by the Quarter Master General's department, and did not arrive at Kampa Dzong until 5th June. While awaiting their arrival, I filled in the time by occupying and re-observing from Colonel Ryder's old triangulation stations of 1903, overlooking the Kampa plain. The arrival of the expedition at Kampa was saddened by the death of Dr. Kellas from heart failure consequent on severe gastritis. He had been unwell almost from the start, but with characteristic determination had refused to give in or to turn back. He was buried the following day on a spur near the dzong, in sight of the three great peaks of Chomiomo, Kangchenjau and Pauhumri, which he alone had climbed. Mr. Raeburn, who was also unwell, was at this point compelled to return temporarily to Sikkim, under Dr. Wollaston's care. The Sikkim revision-survey having been so much delayed by bad weather, I decided to take only two of the surveyors with the expedition into Tibet, leaving surveyor Torabāz Khan to complete the comparatively dry areas of northern Sikkim before the arrival of the monsoon. This he succeeded in doing at the cost of considerable personal discomfort, returning to Darjeeling in July.

Resuming our march on 8th June, Tengkye Dzong was reached in two stages. Here a day's halt was necessary while fresh transport was being collected. Up to this point, I had managed to carry on a rapid triangulation while keeping pace with the remainder of the expedition. I realised, however, that with daily marches averaging 15 to 20 miles this would no longer be possible, and that it was necessary to decide at once whether to delay the surveyors sufficiently long to enable a triangulation to be carried forward, or, alternatively, to allow them to keep pace with the expedition while merely utilizing the previously existing triangulated points, of which a fair number were visible. In view of the obvious signs of a rapidly approaching monsoon, I decided in favour of the latter alternative.

From Tengkye we marched in 6 stages to the next dzong, Shekar—crossing the broad sandy bed of the Shiling river a mile above its junction with the Phung Chu. Owing to the prevalence of rinderpest in the Phung Valley, the transport yaks and bullocks provided by the dzongpen of Tengkye had to be replaced by donkeys for the two last marches before reaching Shekar.

The Phung river is remarkable for the amount of mud which it carries in suspension: below Shekar it flows through a wide, open valley with occasional stretches of fertile marshland, and scattered clumps of a stunted species of *salix* resembling sea-buckthorn, known in Tibetan as "lamdse." Flowering clematis everywhere abounds, and a sweet-smelling valerian or candytuft—the latter is said by the Tibetans to be very poisonous, and is carefully avoided by cattle.

The town of Shekar is situated five miles north of the Phung Chu, on the edge of a level plain containing numerous irrigated fertile barley-fields, with scattered hamlets and *gömpas*. The large monastery of Shekar Chöte is finely situated on a commanding hill behind the town to which it gives its name—Shekar being an abbreviation of "Shel Karpo" (white glass), in allusion to the numerous windows and conspicuous whitewashed walls of the monastery, which glisten in the morning sun. At Shekar, transport requirements once more necessitated a day's halt, on 17th June; this we utilised in visiting in turn the dzong and monastery, where we were hospitably received. A sharp shower of rain fell in the evening, a forerunner of the coming monsoon.

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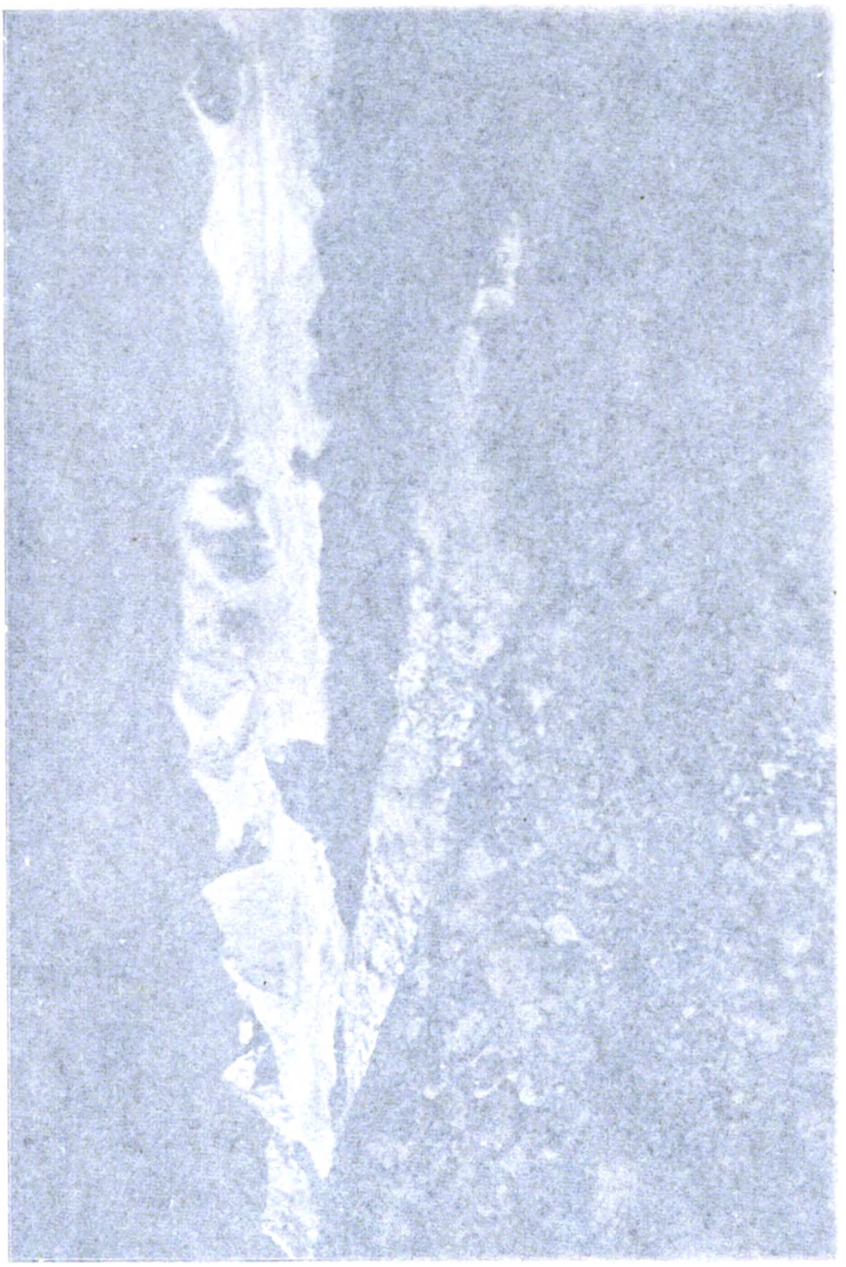

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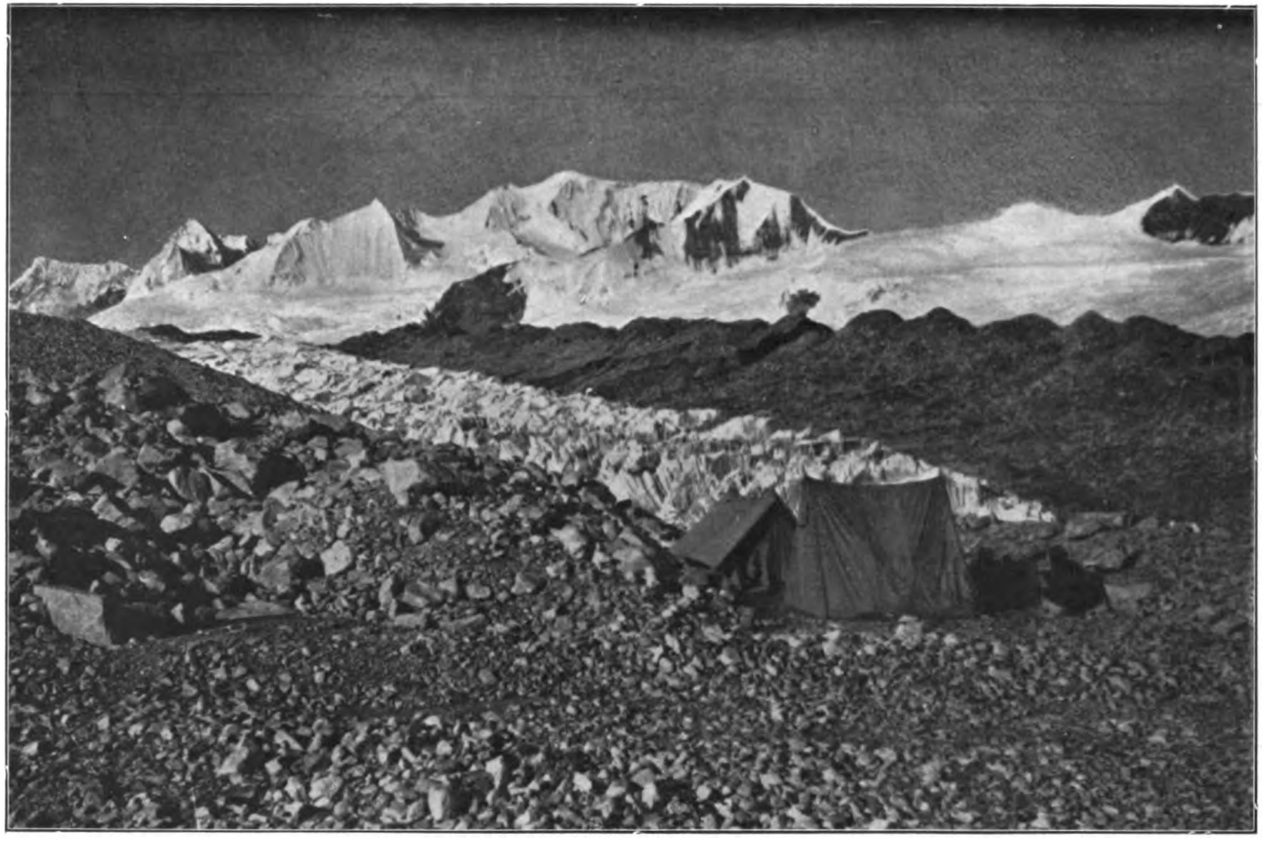

HIGH CAMP ON KYETRAK GLACIER.

Photo by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta. 1923

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RA CHU AND KYETRAK GLACIER, LOOKING TOWARDS NANGPA LA.

Photo. by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1923

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Resuming our journey up the Phung Valley, Tingri was reached in two long marches on 19th June. Tingri possesses no dzong, its affairs being managed by a *nyerpa* or steward, subordinate to the dzongpen of Shekar. It is also the peace-time headquarters of a Tibetan general; the present incumbent was however absent on active service in Kham, and his duties, which mainly consist of safeguarding the annual tribute paid to the Nepāl Darbār, were being carried on by a civilian agent and a couple of soldiers. This tribute, amounting to 60 *dotse* (Rs. 5,000) annually, has been paid by Tibet every November since the last Gurkha invasion in 1854, when the Gurkha forces reached almost to Shigātse.

The village of Tingri or Gangkar (white spur) is built on the slopes of a low isolated hill in the middle of an extensive alluvial plain. The hill is crowned by the remains of a Chinese fort, now abandoned; just below is the erstwhile residence of the Chinese commandant—a building now used as a "circuit-house" for Tibetan officials when on tour. This was destined to be the headquarters of the expedition for the next six weeks, and formed a convenient centre for various scientific excursions into the surrounding districts; a dark-room was installed in which Abdul Jalil was kept busily employed in developing the photographs taken by the several members of the expedition.

After a few busy days spent in sorting and arranging kit, Col. Bury accompanied by Dr. Heron, started on a hasty reconnaissance of the tracts of country known as Phāruk and Khārta, lying to the north and east of Mt. Everest, with the object of settling on a suitable site for the next headquarters when a further move should become necessary. Bullock and Mallory set off to examine the north-west approaches of Mt. Everest, and to train the coolies in ice, snow and rock technique. Major Wheeler commenced his photo-survey in the neighbourhood of Kyetrak, two marches to the south. Leaving Lalbir Singh at headquarters to complete and ink-up his plane-table, I started with Gujjar Singh to explore the western tributaries of the Phung Chu. The first day's march led us past the hot spring at Tsamda into the broad Sutso plain. Turning westwards at Gutso, two more marches brought us to Menkhaptö. Eight miles beyond this village, the road crosses a high spur known as the Lungchen La, from which a good view is obtained over the whole Pekhü plain, which extends 20 miles to the west. This plain is almost uninhabited, and its features can be sketched from a couple of fixings on either side of the Lungchen Pass. Bad weather had now set in, and the snowy range forming the western boundary of the plain was hidden in cloud. I therefore left Gujjar Singh camped on the pass to await a favourable opportunity for completing the survey of this area, and myself returned to Tingri at the end of June, rejoining Dr. Wollaston who had been detained by an outbreak of enteric fever among the expedition servants.

The next few days were spent in examining Lalbir Singh's work, and correcting his list of village-names with the assistance of the local Tibetan officials, after which he departed on a lengthy programme of work in Phāruk and Khārta. It was three months before I saw him again.

About this time, a messenger arrived from the dzongpen of Nyenam, inviting us to visit his district which lay four marches to the south-west, in the valley of the Pö Chu, or Bhotia Kosi river. Although Nyenam was not one of the districts specifically mentioned in our passport, we decided, with the concurrence of Col. Bury who had meantime returned to headquarters, to avail ourselves of the opportunity of visiting this little-known area. Leaving Tingri on 13th July, Wollaston and myself, with surveyor Gujjar Singh and interpreter Gyaldzan Kāzi, camped that night at Lungkor, a small village at the western edge of the Tingri plain. There is here an interesting temple, said to be over 1,000 years old, containing a stone which is alleged to have been thrown over the Himālaya Range from India and to have pitched on the Tingri plain, whose name is derived from the noise ("ting") made by the falling stone. The stone is carefully preserved inside a wooden box which is opened with much ceremony on the first day of the Tibetan new year.

Crossing the Thung La (17,980 ft.) in a driving snowstorm, a long march of 22 miles brought us next day to the village of Tulung in the valley of the Pö Chu. Two days later we reached Nyenam (12,500 ft.), a large and very insanitary village which is known under the name of Kūti by the Nepālese who constitute the majority of its inhabitants. These Nepālese traders (Newārs) have their own Hindu temple in the village; there is also a Nepālese *chauki* with a *hākim* (magistrate) having summary powers of jurisdiction over Nepālese subjects. He is specially charged with the settlement of trade disputes, and the encouragement of Tibeto-Nepālese trade and commerce.

As is customary in all important districts of Tibet, there are here two dzongpens who, by a polite fiction, are known as "eastern" and "western" (*dzongshar* and *dzongnup*) respective-

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ly. Actually, the functions of the two dzongpens are identical—the *raison d'être* of the double *régime* being an attempt to protect the peasants from extortion by the device of providing two administrators who, in theory at least, act as a check upon each other's peculations. At the time of our arrival, these two worthies were so busy preparing a picnic that we had considerable difficulty in getting their attention.

I spent three days in exploring the neighbourhood of Nyenam, while Wollaston was engaged in his botanical and zoological pursuits. Gujjar Singh with the plane-table being detained by bad weather higher up the valley, I was reduced to rough route-traverses by prismatic compass for this portion of the map. Below Nyenam the river enters a very narrow gorge, while pines and other forest trees begin to appear; the road, which here becomes impassable for animals, crosses the river four times in eight miles before reaching the village of Choksum, but I could find no trace of the portion described by explorer Hari Rām in 1871 as consisting of slabs of stone 9 to 18 inches wide supported on iron pegs let into the vertical face of the rock at a height of 1,500 ft. above the river. At Choksum (10,500 ft.) the river falls at the average rate of 500 ft. per mile. The Nepāl frontier is crossed near Dram village some 10 miles below Choksum, but owing to the vile state of the weather, which rendered even the roughest attempts at surveying impossible, I abandoned my idea of reaching the spot.

On 20th July we returned 9 miles up the valley to Trashigang, where we found Dr. Heron encamped, together with Gujjar Singh whose work had been hung up for a week by continued cloud and rainfall. Heron went northward next day, while we followed a rough easterly track leading over the Lapche Range to the village of the same name in the valley of the Kang Chu. The weather on this day was atrocious and our last pretence of plane-tabling from fixed points broke down, leaving no alternative but a rough traverse by "time and compass" until we joined up with our earlier work at Kyetrak ten days later. We were unable to reach the village by dusk, and spent a somewhat miserable night camping on boulders in drenching rain at 14,600 ft. with no fuel except a few green twigs of dwarf rhododendron.

Lapche (La-rinpoche = "precious hill") is sacred as the home and birth-place of *jetsün* Mila Repa, a wandering lama and saint who lived in southern Tibet in the eleventh century, and whose collections of songs and parables are still among the most popular books in the country. His hermit-cell still remains under a rock on the hillside, and his memory is preserved by an ancient temple, the resort of numerous pilgrims, alongside which we pitched our tents.

The extreme dampness of the Lapche climate is indicated by the trailing streamers of lichen which festoon the trees, and by the pent roofs of the buildings. The village only contains some eight or ten houses, of which half are occupied by Tibetans and half by Nepālese subjects (Sharpas), each community having its own headman. The inhabitants were very friendly and pleasant, and gave us much interesting information. The village is deserted during the winter months, when the whole population migrates across the border into Nepāl. The Tibetans pay no taxes to Nepāl during their half-yearly sojourn in the lower valley, while conversely the Nepālese during their summer residence in Lapche are not subject to Tibetan taxation or to the imposition of "*ulag*" (forced labour, or "*begār*"). Kātmāndu can be reached from Lapche in eight marches, but the track is bad and very little trade passes this way. Gujjar Singh utilised a day's halt in running a traverse down the valley as far as the Nepāl frontier.

From Lapche we proceeded to the Rongshar Valley, crossing the Kangchen and Kangchung passes. Descending the hill to Trintang village where we camped, the clouds lifted momentarily, disclosing an amazing view of the superb peak of Gaurī Sankar towering magnificently above us just across the valley. This mountain, which the Tibetans call Chomo Tshering or Trashi Tshering, is the westernmost of five very sacred peaks known collectively as Tshering Tsenga ("Tsering five-peaks"). Unfortunately, owing to constant clouds, I was unable to identify with certainty the remaining four peaks of Thingki Shalzang, Miyo Lobzang, Chopen Drinzang and Tekar Drozang. Owing to the sacred nature of the Rongshar Valley, the slaughtering of animals is forbidden, and the large flocks and herds of the villagers are only kept for sale in Tingri and Nepāl. We were only able to buy a sheep on promising not to kill it until after quitting the valley.

Trintang village occupies a plateau 1,750 ft. above the level of the Rongshar river; 1,400 ft. below is the village of Tropde, to which the Trintang residents all descend in winter. Rongshar Dzong, which is situated in the lower village, has no importance; at the time of our visit the dzongpen had gone on a holiday, leaving his affairs in the hands of a steward. A day's halt being necessary in order to collect transport, I took the opportunity of descending the

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TIBETAN DANCERS AT LINGGA.

BREAKING CAMP AT GYANGKAR NANGPA.

Photo. by Major Wheeler.

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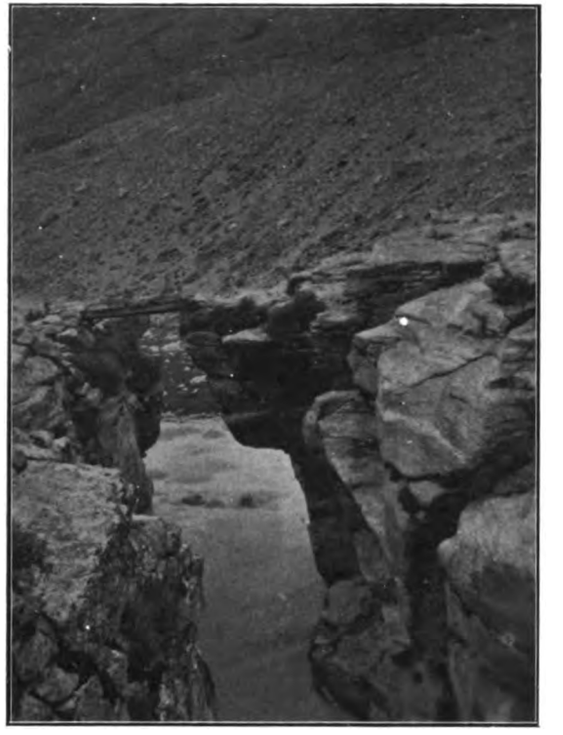
FOOT-BRIDGE OVER RONGBUK R. AT CHÖBU.

ROPE-BRIDGE OVER PHUNG CHU AT GARTHONG.



FOOT-BRIDGE AT GORGE 6 MILES ABOVE CHÖBU.

Photo. by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1923.

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Rongshar Valley as far as the Nepāl frontier, while Gujjar Singh endeavoured, without much success, to pick up the threads of his survey by identifying the snow peaks which occasionally afforded us brief glimpses through rifts in the clouds. The Rongshar Chu falls 1,400 ft. in the seven miles between Tropde and the Nepāl frontier, which it crosses at an altitude of roughly 9,000 ft.

On 27th July we marched 20 miles up the Rongshar Valley to the village of Tāsam (Takpa-santsam = "limit of birch-trees") which, as its name implies, is situated at the extreme upper limit of the forest zone. On the way we passed the village and monastery of Chuphar, whence a track leads southwards over the difficult snow-pass of Menlung ("valley of medicinal herbs") to the villages of Rowaling and Tangpa in the Kangphu Valley of Nepāl. The headman of Tāsam was too drunk, on the evening of our arrival, to send out the necessary messages summoning yaks from the grazing grounds. In consequence, our baggage next day only got started at 11 a.m., and we were compelled to pitch our tents at a grazing camp after covering only nine miles. The weather showed signs of improvement in proportion as we receded from the Himālayan gorges, but dense banks of cloud still obscured all the hill-tops. An easy march over the Phüse La brought us on 29th, to the bleak village of Kyetrak at the extreme southern edge of the Tingri plain, an area which had already been surveyed from Tingri.

Four days later we rejoined the expedition headquarters which Col. Bury had just transferred to Khārta, in the lower valley of the Phung Chu. Khārta is a scattered district, administered by a steward who is directly under the Lhāsa government and independent of the Shekar dzongpen. The valleys are dotted with picturesque hamlets and scattered farmsteads surrounded by irrigated fields of barley, mustard and dwarf pea. Numerous tall poplar trees give a distinctive and unusual appearance to the landscape, and form the nesting-places of countless magpies.

The weather during the whole of August rendered out-of-door work almost impossible. Gujjar Singh was occupied during the month in adjusting his traverse, while I endeavoured to fill in the time by making progress-traces of all work so far completed. I also spent ten days with the mountaineers, Mallory and Bullock, on a reconnaissance at the head of the Khārta Valley, when the route was decided on for the season's final high climb, after the monsoon should have abated.

Major Wheeler returned to headquarters on 27th August, having had a very rough and unpleasant time in the Rongbuk Valley, almost due north of Mt. Everèst. It is difficult for those who have not actually had the experience, to conceive the degree of mental and physical discomfort which results from prolonged camping during the monsoon at heights of 19,000 ft. or more, waiting for the fine day which never comes. Such had been Wheeler's fate ever since leaving Tingri three months previously.

On 1st September we were surprised by the unexpected return of Mr. Raeburn, who had completely recovered from his indisposition, and who brought with him a welcome gift of apples and corn-cobs from the kind-hearted ladies of the Scandinavian Mission at Lachen.

As the weather now showed slight signs of improvement, it was decided to move to an advanced base-camp 20 miles up the Khārta Valley at a spot known as Khārtaphu (17,500 ft.), whence further preparations could be put in hand for the final high climb. Mallory and Bullock had already left on 31st August, and were followed on 5th September by Col. Bury, Raeburn and Wollaston. After starting Gujjar Singh on an area of 1-inch plane-tabling north of the Khārta Chu, I joined Wheeler during his photographic survey of the Khārta Valley; the weather, as usual, greatly delayed his work, so that we only reached Khārtaphu on 12th. Here there was yet another week of tedious waiting before the weather improved sufficiently to warrant a further move to No. 1 advanced camp, where fuel, stores and mountain tents had already been dumped in advance. The camp was pitched at 20,000 ft. on a stony ledge overlooking the Khārta glacier 500 ft. below. From here, a further consignment of tents and stores was carried to the site of No. 2 advanced camp, on the summit of the col (22,200 ft.) at the head of the Khārta glacier.

After resting the coolies for a day, we all moved up to No. 2 advanced camp on 22nd September. The track led over the Khārta glacier, the surface of which was in good condition, so that the last coolie had arrived by 11 a.m. The wind on the summit of the col was terrific, but unfortunately no other sufficiently level stretch of snow was available on which to pitch the tents. We named the spot Hlakpa La ("windy-gap"). Wheeler's camera and theodolite station on the col is probably the highest station of observation which has

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ever been made. His instrument was supported by ration-bags of *tsampa* (parched barley flour) on the snow. The night temperature fell to zero F.

One or two of the coolies collapsed with mountain-sickness after reaching the col; but apart from this, few of us suffered any worse effects from the height than a general feeling of lassitude, and considerable insomnia at night. Our party, consisting of 6 Europeans and 18 coolies, was, however, obviously too large and unwieldy for work at high altitudes. It was therefore decided that only the three experts,— Mallory, Bullock and Wheeler—with 10 coolies and three days' supplies, should go forward to the third advanced camp; the remainder of the party descended again on 23rd September to No. 1 camp to await their return. The mountaineers returned to No. 1 camp two days later, having reached a height of approximately 23,000 feet on the col due north of Mt. Everest, from which point they were compelled to turn back by the terrific gales of wind, which lifted dense clouds of snow into the air and threatened them with suffocation.

The following day, Bury, Wollaston and Wheeler departed southwards for a five-days' tour of the upper Kārma Valley, while the remainder of the party returned by easy stages to Khārta, bringing all the tents and equipment.

The return journey to Darjeeling was made by the various members of the expedition in several different detachments. Accompanied by Gujjar Singh, I left Khārta on 2nd October and ascended the Phung Valley for three marches, rejoining the outward route of the expedition at Shiling. From Gyangkar Nangpa I despatched Gujjar Singh to complete the remaining portions of the Sikkim revision; at the same spot I picked up Lalbir Singh, who, after completing the Phāruk and Khārta areas, had crossed the Phung Chu below Lungtö and worked his way back *via* Tāshirāk and Sār. Travelling *via* Kampa and the Lachen Valley, we reached Darjeeling on 16th October. By 25th October the whole expedition had returned except Gujjar Singh, whose work in Sikkim detained him until early December.

Fair-traces of the whole original ¼-inch survey had been kept up as far as possible during the expedition; these were completed in Darjeeling and despatched to the Photo.-Litho. Office for vandyking, so that a preliminary map printed in six colours was available before the last members of the expedition had sailed from Bombay.

Previous Travellers.

The earliest recorded European travellers in the area, are the German Jesuit Johannes Grueber and his Belgian companion Albert de Dorville in 1661-62. Grueber, who occupied the position of mathematician to the Court of Peking, received a summons to Rome early in 1661. The sea-route being closed owing to war with Holland, Grueber was instructed to discover a route to Europe overland. Travelling by way of Sining Fu and Lhāsa, he thence proceeded south-west to Kātmāndu and India *via* Kūti (Nyenam) and the valley of the Bhotia Kosi river,—finally reaching Italy through Makrān, Persia and Asia Minor. Grueber made sketches of his route, and also carried an astrolabe with which he took occasional observations for latitude. His results exhibit a general mean error of about half a degree.

During the first half of the eighteenth century there appears to have been frequent traffic across the Himālayan passes between the Capuchin mission then existing at Kātmāndu and the various branch establishments in southern Tibet. The only journey, however, of which a record exists is that of Cassiano Beligatti de Macerata, one of a party of ten Capuchin brethren returning from Europe to re-establish the mission at Lhāsa. Leaving Patna in December 1739, the party remained at Kātmāndu (then only a provincial town) until after the rainy season of 1740. Their route led through Kūti and the Tingri plain to Sakya and Gyāntse; Beligatti's description of the country and people might well have been written today.

It was while the Capuchin missions were still in existence, between the years 1723 and 1736, that the adventurous Dutchman Samuel Van de Putte visited Tibet in the course of his remarkable 20-years tour from Aleppo to Peking. He appears to have been an excellent Tibetan scholar as well as a skilled and competent observer, but on his death (in Batavia on his way home in 1745) his papers were all burnt under the terms of his will. His sketch map of southern Tibet, which is however still extant, gives the positions of Kūti, Tingri and the Phung Chu.

From the final closing of the missions in 1745, there is no further record of travel in this portion of southern Tibet until the period of the Survey of India trained native explorers, a century and a quarter later. Explorer "m.H." (Hari Rām) in the course of his first journey in 1871-72 entered Tibet *via* Wālung, Tashirāk and the Nye La, whence he proceeded over the Tengkye Pass to Shigātse. Turning westwards from here, he followed the Chiblung

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PANORAMA OF MT. EVEREST, WITH ITS N & W RIDGES, FROM W. RONGBUK GLACIER.

Photo. by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta. 1923.

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MOUNT EVEREST, NORTH COL AND NORTH PEAK, FROM HLAKPA LA.

Photo. by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1923.

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Mount Everest, North Col and North Peak, from Head's [illegible]

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stream to its junction at Shiling with the Phung Chu, which latter valley he ascended as far as Tingri. Crossing the Thung La he returned to India by way of Nyenam (Kūti) and Kātmāndu.

On his second journey in 1885, accompanied by his son, "m.H." again visited Tingri—travelling on this occasion *via* Nepāl, the Nangpa (or Kangphu) Pass and Kyetrak. From Tingri he ascended the upper valley of the Phung Chu, thence continuing past the Pekhü (Palgu) lake and plain to Dzongka and Kirang. His work is very accurate and reliable.

Another explorer, "G.S.S.", in 1886 ascended the Arun valley as far as Khārta district, the whole of which he places 15 miles too far to the north. His work was regarded with suspicion at the time, and his report was not thought sufficiently reliable for publication.

Babu Sarat Chandra Dass and his companion, lama Ugyen Gyatsho, on their second expedition in 1882, entered Tibet *via* Tashirāk, the Langphu La and Sar. They traversed the Chiblung Valley twice during the course of their journey, but undertook no surveying.

The first rigorous survey, based on triangulated points, undertaken in this area, was that carried out under Capt. Ryder, R.E. (now Colonel C.H.D. Ryder, C.B., C.I.E., D.S.O., Surveyor General of India) during the Tibet Mission of 1903-04. During the stay of the Mission at Kampa, the ¼-inch survey was carried as far west as longitude 88° approximately. On the return-march up the Tsangpo Valley, accurate ¼-inch surveys were extended as far as the southern watershed of the great river, in latitude 29° approximately (the so-called Ladākh Range).

There thus remained a stretch of unsurveyed country, some 65 miles wide by 225 miles long, between the Ladākh and the Great Himālaya Ranges—the latter forming the northern frontier of Nepāl. The Mt. Everest Expedition provided an opportunity of surveying the whole of this area,—with the exception of some 2,000 square miles at the extreme western end, comprising the districts of Kirang and Dzongka, into which, in view of restrictions imposed by the Foreign Department, I did not feel justified in penetrating.

Brief Description of country.

The northern portion of the area, which we passed on the outward journey, consists essentially of flat alluvial plains and wide valleys 13,000 to 15,000 ft. in altitude, bounded by bare rolling hills of Jurassic shale and sandstone, rising to 18,000 and 19,000 ft. Occasional granite peaks of 21,000 ft. outcrop along the axes of the Ladākh Range and of the meridional range of Nyönno Ri ("madman's hill") on the eastern bank of the Phung Chu. The permanent snow-line is about 20,000 ft. As one goes southward the valleys become narrower; the sandstones are metamorphosed into quartzite, and crystalline schists become more and more common. Finally, for a zone of perhaps 30 miles in width in the central belt of the Great Himālaya Range, the rocks consist entirely of crystalline granite, gneiss and schist.

A short description of the Nepāl-Tibet frontier may be of interest. Commencing from the western edge of the map, the frontier is represented by the sharp range of peaks running south-eastwards from Gosainthān. Crossing the Pö Chu (Bhotia Kosi) above the village of Chenegang (some 20 miles below Nyenam), where a Nepālese guard is stationed, it maintains a general easterly direction, crossing the Kang and Rongshar rivers a few miles above their junction. Thence, passing through the summit of Gaurī Sankar, it runs in a north-easterly direction to the Nangpa (Kangphu) Pass. From here, after following the chain of high snow-peaks known as Cho Oyu and Gyāchung Kang, it turns south-eastwards along the Mt. Everest-Makalu ridge, past the Popte La, where a masonry pillar indicates the frontier. Crossing the Phung Chu (Arun river) two miles below Kyimatang, at a height of roughly 7,500 ft., it follows a spur leading north-eastwards past Ritak (where a masonry pillar again marks the frontier) to the Rakha La (16,250 ft.), whence it turns sharply south, following the main range to the Tipta La (17,400 ft.). After running eastwards for 7 miles, it again turns north-east for 16 miles to the snow peak of Langphu (21,500 ft.), whence it proceeds due east to the trijunction of Tibet, Nepāl and Sikkim at the Jonsong Peak (24,350 ft.).

Summary and Conclusion.

The place-names occurring on the map have in nearly every instance been spelled in the vernacular by local officials, whom I found very ready to assist in the matter. In the case of rivers which rise in Tibet, such as the Pö Chu (Bhotia Kosi) and Phung Chu (Arun), the Tibetan name has been used for the portion north of the frontier. In the case of the latter river, I have adopted the name "Phung Chu" in preference to that of "Yaru Tsangpo" by which the lower portion of its Tibetan course has sometimes been shown on old maps. The former name is used by 9 out of every 10 Tibetans; in fact I only once heard the name "Yaru Tsangpo" used, and then it was applied merely to the Kampa branch of the river, by the villagers of Rongkong.

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Actually, "Yaru" is an adjectival form of the word *Yarka* (summer), and is applicable to any river which overflows its banks during the summer months. If "Yaru" is to be accepted as the proper-name for any individual river, it would appear preferable to reserve it for the big Tsangpo (Brahmaputra) river of Tibet, as was done by Hooker and the earlier writers.

In the case of snow peaks on the main Himālaya Range, both the Tibetan and the Nepālese names have in most instances been given. The local Tibetan name for Mt. Everest, "Chomo Longma", is an abbreviation for "Chomo Lo-Zangma" ("liberal-minded fairy"). We were unsuccessful in obtaining any corroboration of the name "Makalu", either from Tibetan or Nepālese sources; the mountain is known locally in Tibet as Chomo Löntso or Cho Löndo.*

In regard to special equipment, little need be said. Khalasis were of course clothed on the "arctic" scale. For levelling tent-sites etc., each squad was equipped with an infantry-pattern entrenching tool obtained from the Quartermaster's Store at Jalāpahār. Special tents were made to my design by the Muir Mills Co., Ltd., of Cawnpore, as follows:—

For officers and surveyors—5 single-fly tents of green rot-proof canvas 6 feet × 6 feet, walls 2 ft. high, with floor of the same material sewn on to the side walls as a protection against wind and drifting sand, weight 50 lbs. each.

For khalasis and coolies —5 single-pole circular tents of green rot-proof canvas 14 ft. in diameter, with side-walls 1 ft. high, the side walls continued inwards for 2 ft. all round, weight 50 lbs. each.

These 10 tents, which were supplied by the Company at the very nominal cost of Rs. 100 each, proved generally very satisfactory, although not thoroughly water-proof in wet weather. For his high camps, Major Wheeler and his coolies used a couple of the expedition light Whymper tents which were kindly lent by Colonel Bury.

The detachment was inspected by the Surveyor General after its return to Darjeeling on 9th-11th November, when it was decided that the fair-mapping should be carried out as follows:—

¼-inch degree sheet 78 A.—No. 1 Drawing Office, Calcutta.

¼-inch degree sheets 71 H, L, and P, and 72 M—No. 2 Drawing Office, Dehra Dun.

With the exception of an outbreak of enteric fever among the domestic staff, one of whom—Major Wheeler's private servant—died at Tingri, the health of the detachment was excellent throughout the season.

The out-turn of work during the seven months' field season is as under:—

¼-inch Revision survey (sheet 78 A, Sikkim, etc.), 4,000 square miles.

¼-inch Original survey (sheets 71 H, L and P), 12,000 square miles.

Detail Photo survey (environs of Mt. Everest), 600 square miles.

The cost of the Survey Detachment up to 30th November amounts to Rs. 65,282, giving an average over-all cost-rate of Rs. 3·9 per square mile.

The surveyors all worked splendidly under difficult and trying conditions. Major Wheeler had probably the hardest time of any member of the expedition, and the fact that he has succeeded in the face of such appalling conditions of wind and weather, in bringing back photographic material for the fair-mapping of 600 square miles of some of the most mountainous country in the world, is sufficient proof of his determination and endurance.

I cannot conclude without a tribute to the very liberal and efficient manner in which the expedition was organised. Everything was provided which experience could suggest as likely to ensure the comfort or enhance the success of the enterprise; while the cordial relations which were everywhere established with the Tibetans, and the happy atmosphere which prevailed among the individual members of the expedition, are eloquent testimony to the tact and ability of our genial leader, Colonel Howard Bury.

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* It is very probable that other Tibetan and Nepālese names for the same peaks are current locally.

The names, Mount Everest and Makalu, are already well known throughout the world and, after much discussion and consideration, it has been decided to retain them on Survey of India maps.

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Photo by MAJ WHEELER. Photogravure, Survey of India Offices, Calcutta, 1933.

MOUNT EVEREST AND SOUTH PEAK FROM NEAR No 1 ADVANCED CAMP.

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II.—Report on the Trial of the Canadian Photo-Topographical Method of Survey.

By Bt.-Major E. O. Wheeler, M. C., R. E.

Introduction.

A trial of this method was carried out with the Mt. Everest Expedition from May to October 1921; a camera and 3-inch theodolite, similar to those in use in Canada, having been obtained from England early in the year. Although the method has been extensively applied elsewhere with marked success, particularly in Canada, it was doubtful whether it could be successfully employed in the deep narrow Himālayan valleys, and whether it could compete with the plane-table on the smaller ($\frac{1}{4}$-inch and $\frac{1}{2}$-inch) scales.

The instruments were received from England early in April. Considerable adjustment and alteration were found to be necessary, particularly in the case of the camera; and the usual tests for the horizon and principal lines, focal length, bubble readings, etc., had to be made. These preliminaries were carried out in Dehra Dūn before starting for Darjeeling.

I reached Darjeeling on April 30th and proceeded with the expedition on May 18th *via* the Dzalep La, Phāri and Kampa Dzong to Tingri, which we reached on June 19th.

Altogether, some five months were spent in the field, of which three were employed on the site of the work and two in marching to and from the work and in developing and printing photographs, of which some 240 were taken in all. It seemed wise to develop in the field to ascertain that exposures were correct, and to guard against possible deterioration of plates on the return march through the damp climate of Sikkim. Prints of some of the negatives were made to assist in the identification of peaks when seen from new angles.

Extent of work.

Mt. Everest lies in latitude N. 27° 59′ 16″·2 and longitude E. 86° 55′ 39″·9 on the backbone of the main chain of the Himālaya and on the Nepāl-Tibet boundary. It is flanked on the west by a high group reaching to 26,867 ft.; to the north by a group reaching to 23,800 ft.; to the east by the Makalu group (27,790 ft.); and to the south by many high peaks. Permission to enter Nepāl not being granted, only the area north of the boundary could be considered. A map which will explain Mt. Everest clearly and will show its connection with neighbouring mountains and with the drainage of its vicinity must include the mountain groups mentioned above. In fact, they, with Mt. Everest itself form one great mountain mass, the whole of which may best be described as the "Everest Group". This classification is borne out by the general topography of the area.

About 20 miles west of Everest and immediately west of Pk. 26,867 (called locally Cho Oyu), the Rā Chu flows north from the Kangphu or Nangba La (on the Nepāl-Tibet boundary) to Tingri where it joins the Phung Chu flowing east; the Phung Chu after following an easterly course for some 65 miles turns south to flow through the main chain about 30 miles east of Everest and close east of Makalu. About 20 miles north of the Nepāl boundary, a tributary of the Rā Chu from the east gives a low pass to the Dzākar Chu, flowing down from Everest, first north and then north-east to join the Phung Chu about 30 miles north of the frontier. These two streams practically form the dividing line between the real mountains on the south and the high rolling hills of Tibet on the north. The area south of these two streams and bounded east and west by the Phung Chu and Rā Chu respectively thus contains a mass of great peaks, including the groups referred to above, which culminate in Mt. Everest in the centre and which all drain eventually *via* the Phung Chu through the Arun gorge into Nepāl.

This area seemed suitable for the experiment. It contained some 1,200 square miles of country—about a season's work, given fine weather—and gave opportunities for photographing all types of country from rolling hills with villages and cultivation, through steep gorges, to glaciers and tremendous snow and ice clad mountains. With Major Morshead's approval, I therefore decided to tackle this area with a view to fair-mapping both on 1-inch and $\frac{1}{4}$-inch scale: the former is the most suitable scale for this method and for the detailed map asked for by the Royal Geographical Society. But it seemed desirable to plot also on the $\frac{1}{4}$-inch scale to ascertain how far the method was suitable for ordinary small scale work and to enable "single ray" work over a larger area to be tested.

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My equipment was divided into four parts:

(1). *Surveying equipment,* consisting of:

Equipment.

3-inch theodolite and stand, in canvas case, weight 27 lbs.

Camera in leather case, also containing 11 filled plate-holders, angle and exposure note books, pencils, waterproof cover for camera and theodolite etc., weight 30 lbs.

18-inch square collapsible *plane-table* to fit on theodolite stand,

and 12-inch sight-rule.

With this was carried a Web Equipment pack containing 13 spare filled plate-holders, a measuring tape and a medical box containing bandages, etc., total weight about 30 lbs.

All the above loads were arranged to be carried on the shoulders like a rucksack, leaving the hands free for serious climbing. They were carried by three selected coolies who were fitted out with warm clothes, boots, blankets, snow glasses, ice axes, etc. A climbing rope was added when necessary. The plane-table, which was plotted on $\frac{1}{8}$-inch scale, was used only for picking up triangulated points; a matter of some difficulty in high mountains where it is very easy to mistake one peak for another. After the first few days, the plane-table was not required, and only two coolies climbed with me, the third acting as spare man. At first I used "Paharis" from southern Nepal: but they were very unsatisfactory at high altitudes. I therefore substituted Bhotias, who proved to be much better both as regards altitude and picking up climbing wrinkles.

(2). *High Camp Equipment*, consisting of:

1 "Meade" tent for myself.

1 "Whymper" for the three "high coolies" who remained with me.

1 Dark tent, for changing plates (not necessary on dark nights).

1 Primus stove for my personal cooking. This was a two-burner "roarer" type which I found to work very satisfactorily up to 19,500 feet. Above that height, spirit stoves or a specially adapted Primus must be used.

1 Petrol tin, filled kerosene oil.

1 or more small tins methylated spirit.

1 or more of the Expedition "high climbing boxes" of food, each calculated to last one man for ten days, and weighing about 30 lbs.

A small supply of aluminium cooking pots and plates etc.

Bedding, consisting mainly of down sleeping bags, a change of clothes etc.

Spare photographic plates.

Coolies' rations, cow-dung fuel and blankets.

With this equipment I slept 41 nights on moraines and glaciers at altitudes between 18,000 and 22,000 feet. It was carried by 10 permanent coolies, who also acted as dâk runners and fuel gatherers, etc. They were not fitted out with warm clothes or light tents, and therefore had always to sleep at the main camp, only coming up to me as required; this considerably restricted my radius of action, but on the other hand reduced the number of coolies I had to maintain. To penetrate to the heads of glaciers of the size here met with however, it is essential to be able to camp at least 12 coolies on ice, and therefore to fit them with boots, warm clothes and mountaineering equipment.

(3). *Main Camp Equipment,* consisting of:

1 Forty pound tent (single fly green canvas, with floor sewn in) for myself.

1 Bell tent for 10 coolies.

1 Kitchen and servant's tent.

Spare Photographic plates, clothes, food, mending gear etc.

This was in charge of one khalasi. My cook-servant remained here and sent up cooked food as opportunity offered. Main camp was usually at the glacier snout at an altitude of 16,500 to 17,500 feet. Local transport was used as required for moving this camp.

(4). *Base Equipment,* consisting of:

Spare photo plates, developing apparatus and chemicals, spare clothing, etc.

Plates were packed in 1-inch deal boxes (tin lined) to contain 9 dozen plates each. The plates (in dozens) were wrapped in thoroughly dried botanical paper, and the boxes soldered up before leaving Dehra Dun. Each box weighed about 32 lbs. filled.

The above arrangements were on the whole satisfactory. More mountaineering equipment and warm clothes for coolies for use if and when necessary, would however have been an advantage.

On June 24th I moved up the Ra Chu from Tingri, and on the 26th, established my Base camp in Kyetrak village 20 miles south of Tingri, and one mile below the snout of the Ra glacier, at an altitude of 16,500 feet.

Narrative.

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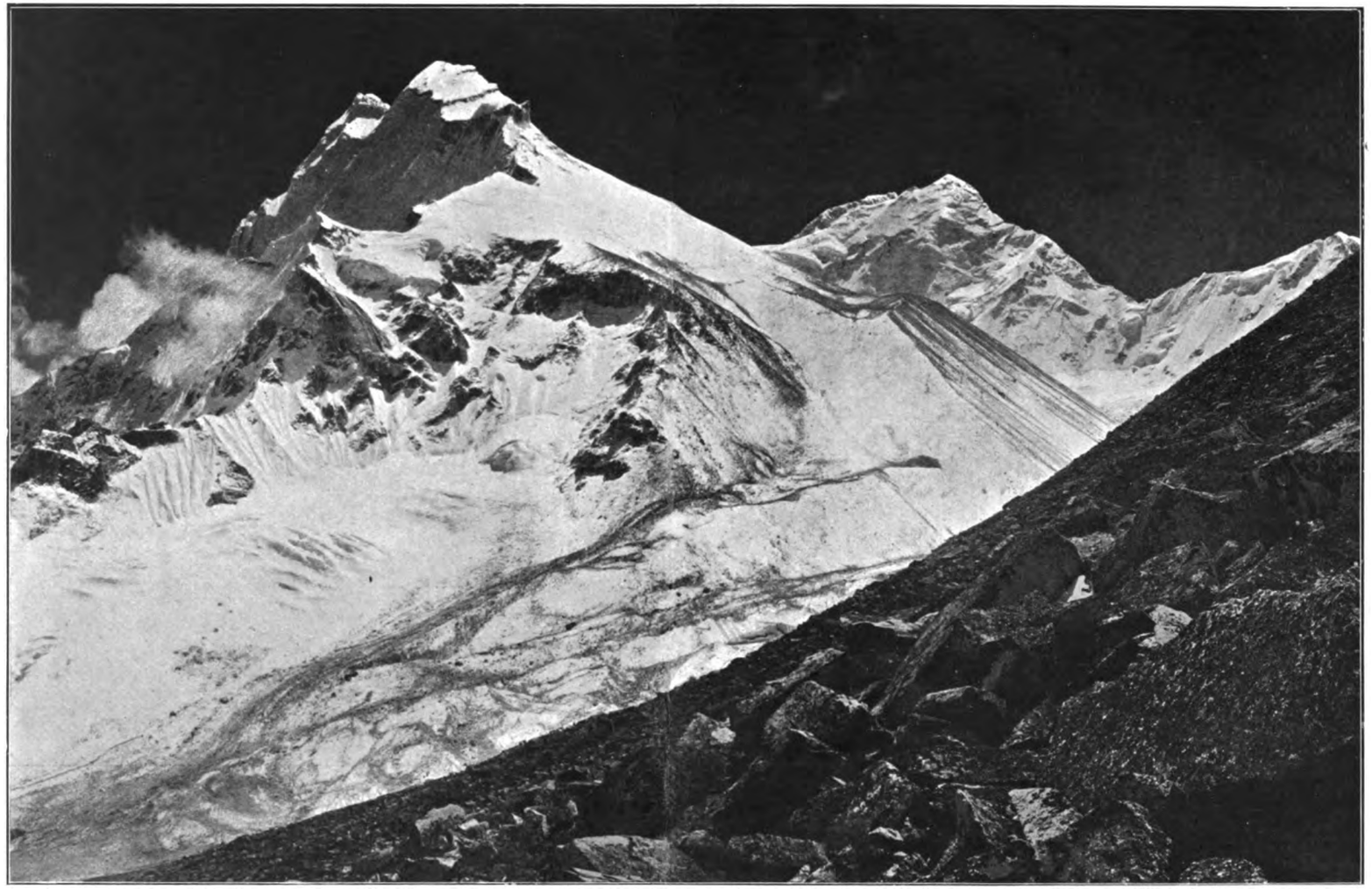

MAKALU, AND MAKALU NORTH PEAK.

Photo. by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta. 1923.

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MAKALU AND UPPER KĀRMA VALLEY, LOOKING SOUTH.

Photo by Major Wheeler.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1923.

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Two fine days at the outset enabled me to identify 26,867 (Cho Oyu), 25,990 (Gyāchung Kang) and 23,440 (Gaurī Sankar), and to photograph the lower glacier and upper valley. But for the succeeding three weeks the weather was bad and I was only able to take 2 more stations on the west side of the valley, and 3 on the east. I waited some days in a light camp high up the glacier in the hope of getting a station to overlook the Nepāl side of the Kangphu La, but eventually was forced to abandon it, owing to shortage of time.

On July 18th, after a fruitless attempt to establish a station on the peak overlooking the junction of the Rā Chu with its eastern tributary referred to above, I moved into head-quarters, leaving my main camp at the bridge over the Rā Chu 6 miles below Kyetrak.

On July 24th and 25th, after completing developing and printing to date, I moved back to the bridge and on to Chöbu on the Dzākar Chu, with Expedition head-quarters. I had intended to try again for the station above the Rā Chu bridge, but as the weather still remained bad and seemed likely to continue so, I decided to push on up the Dzākar Chu towards Everest, to make certain of the more important portions of the work, returning afterwards to the bridge station if time allowed.

Again fine weather on the first day enabled me to obtain a good idea of the country from an 18,000-foot hill 3 miles south of Chöbu and about 25 from Everest in an air line.

The Dzākar Chu, up which there is a good track on the right bank as far as the snout of the glacier, (about 15 miles from Chöbu) is a large unfordable stream, bridged only at Chöbu and at a very narrow gorge about 6 miles above. 10 miles from Chöbu is Chöling monastery, and above that only a few hermits' cells. 3 miles above Chöbu, a large stream from the Gyāchung glacier and Gyāchung Kang (25,990 ft.) joins the main stream on the left bank. My intention was to work up the right bank, cross on the glacier, work down the left bank to the Gyāchung Valley, up the latter to the Gyāchung glacier, again cross the ice and down to Chöbu. Accordingly, I moved my main camp first to the monastery, and then to the glacier snout, (17,500 feet) taking 2 stations on the right bank en route. But the weather went from bad to worse; I was never able to complete a station without sitting through one or more snow storms, and on one occasion, went up a 20,500-foot station three days running only to get some very indifferent photographs late on the third day. Great glaciers join the main Rongbuk glacier from the east and west about 3-4 miles above its snout. I was unable to penetrate to their heads; but secured sufficient photographs to map them fairly accurately. The east branch flows down from a col between the N.E. ridge of Everest and Pk. 23,800, and the west branch from an ice pass to Nepāl south of Gyāchung Kang (25,990 ft.) past the end of the N.W. ridge of Everest. One station on either side of each glacier was taken, and one on each bank of the main glacier; and on the way down, one near the mouth of the Gyāchung Chu, on the left bank of the main river. I was forced to abandon the Gyāchung Chu altogether, except for views obtained at my first 18,000-foot station, and returning to my old station near the bridge over the Rā Chu was out of the question. On August 23rd I returned to Chöbu, having had only one really clear morning in a month, and having occupied only 10 stations in that time. I had hoped while en route to Khārta, the new Expedition head-quarters, to take stations giving views up the Hlelung and various other valleys flowing north from the 23,000-foot group to join the Dzākar Chu; but the weather again prevented me, and I saw little but clouds all the way.

I reached Khārta on August 27th, and spent 6 days there developing and printing.

On September 3rd, I started with Morshead up the Khārta Chu towards the base camp at 17,500 feet, which had been established in preparation for the final attempt on Mt. Everest. On the 4th, we occupied a useful 16,600-foot station 5 miles up the river, and on the 5th, moved 7 miles to a camp in which we were held up for 6 days with bad weather, and which we finally had to leave without being able to occupy more than a very indifferent station, so as to reach the base camp in time to move on with the Expedition.

Our hurry was unnecessary, for another 8 days were spent here, mostly in snow and cloud; two fine mornings however, enabled me to take useful stations on either side of the valley, and on September 19th, I moved up to "No. 1 Camp" (about 20,000 feet) with Morshead, Mallory and Bullock, taking a station en route. The weather was now greatly improved, except for high winds, and I was able to get two stations done, one on either side of the valley before moving with the Expedition to "Hlakpa La" Camp (22,200 feet) on September 22nd. It was too windy for work on the 22nd, but on the 23rd morning the wind died down somewhat and we occupied an excellent station, connecting up with my previous work in the east branch of the Rongbuk glacier. I found that both theodolite and

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camera would remain steady with the tripod resting either on ice axes or bags of grain, although the snow was so soft that one sunk in half way to the knees.

On the 23rd, I left my instruments at the 22,200-foot camp and went on with Mallory and Bullock to the foot of the North Col (between the Main and North Peaks of Everest) where we camped on the glacier at about 21,500 feet. We had first to descend some 1,500 feet of snow to the East Rongbük glacier, and crossing the latter, ascend its tributary flowing down from between Everest and its North Peak.

The morning of the 24th was bitterly cold, but we made a start about 7-30 a.m., with three coolies, and in 2½ hours reached the north col (about 23,000 ft.) after a grind up steep soft snow. From the col we had an excellent view of the north ridge of Everest, but were unable to stay long or go further on account of the very strong wind blowing.

The next day, we rejoined the remainder of the expedition at No. 1 Camp, picking up the instruments, etc., left on Hlakpa La en route. The high wind persisted, making any further attempt on Mt. Everest quite out of the question.

Next day, the 26th, Bury, Wollaston and I crossed a snow pass to the Kārma Valley and camped at 16,500 feet at a grazing camp known as Petāng Ringmo. I established a station en route, and another on the south side of the valley the following day. But the weather on the next few days was very bad and I could do no further work, though I spent the days on the tops of hills, hoping for the clouds to lift. The Kārma Valley is by far the most beautiful I have been in, and it was with great regret that I left it on September 30th to return to Khārta *via* the Shāok La, without having seen more than its upper reaches.

4 days were spent in Khārta completing final development of plates; on October 5th I left with Bury and Wollaston, and arrived in Darjeeling *via* Lachen and the Tīsta Valley on October 20th.

3 weeks were spent in Darjeeling printing photographs and making a rough ½-inch sketch map of Everest and its environs, which was completed before the end of November. Until the final map on the 1-inch scale is completed, it is difficult to say whether the method under trial will be suitable for this country or not; it is undoubtedly more suited to a country like Canada with broad open valleys and comparatively low peaks, but at the same time has many advantages over the plane-table in intricate country. Its greatest advantage is probably that of being able to compare at leisure several photographs from different points of view, instead of having to sketch on the spot, in all weathers, and often largely from memory, the complicated jumble of peaks and glaciers and valleys which comprise the greater part of the Himālayas.

The area attempted had to be very greatly curtailed owing to the continuous bad weather experienced, data being collected for the mapping of some 600 square miles only. There is no doubt that the monsoon, as far as clouds are concerned, affects the northern as much as the southern slopes in this part of the range, though the actual precipitation on the north side would appear to be much less.

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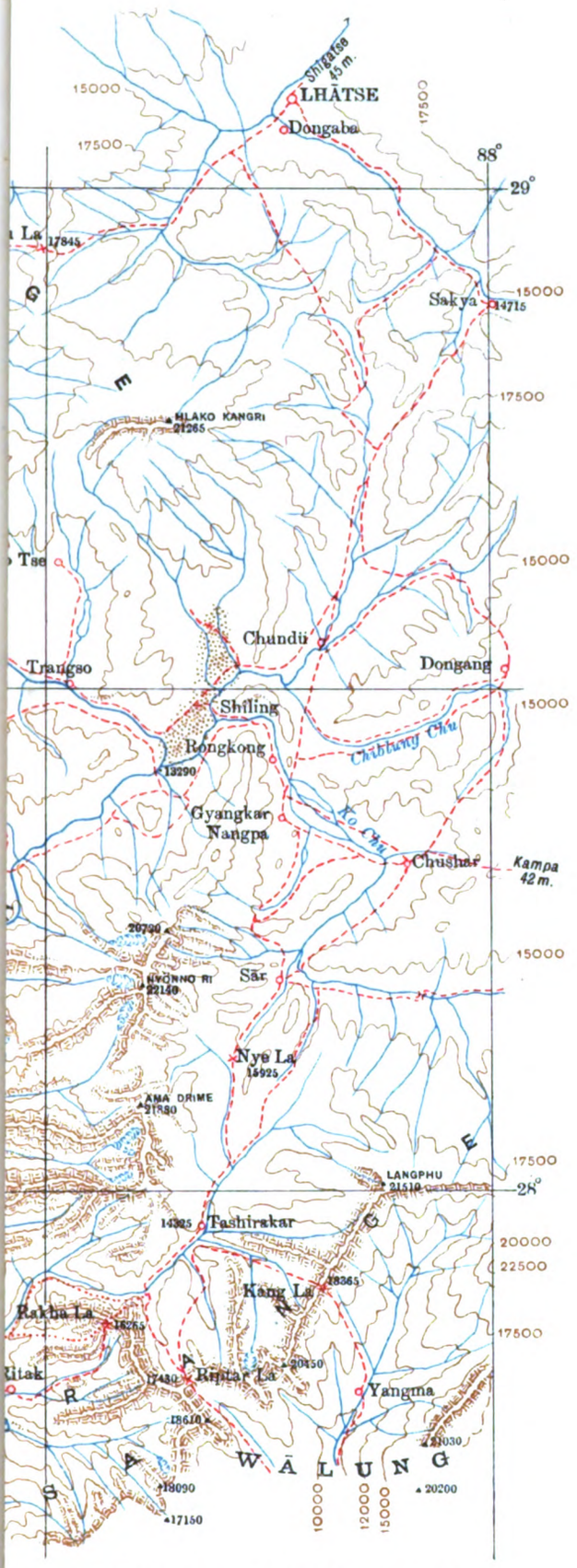

iozincographed at the Survey of India Offices, Dehra Dun.

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TRAVERSE SURVEY OF ALLAHABAD CITY.

By Bt. Lieut.-Colonel S.W.S. Hamilton, D.S.O., R.E.

In 1919 the Allahābād Improvement Trust decided that a large scale survey of Allahābād city and municipal area was essential before any improvements could be commenced. At the instance of the Governor of the United Provinces, the necessary traverse survey was undertaken by the Survey of India and the Officer in charge No. 2 Party was instructed to carry out and supervise the work. At a meeting held in Allahābād in November 1920 between the Trust authorities and Bt. Lt.-Colonel S.W.S. Hamilton, D.S.O., R.E., it was decided that the scale of detail survey for the city and more congested areas should be 64 inches to one mile and for the remaining portion of the municipal area 16 inches to one mile. All preliminary arrangements were made and agreed to at this meeting.

From the experience gained by the Lucknow Improvement Trust, it was known that considerable difficulty was found in preserving the traverse stations. In Lucknow, stone blocks 2 feet long by 4 inches square had been used but had almost all disappeared by the time the detail survey had been completed. In Allahābād therefore it was decided to use 3 feet long by 1 inch diameter iron bars with a suitable cross head which would be difficult to remove. Except in main roads and thoroughfares, the same trouble has been experienced and latterly in the back areas 4 bricks embedded in the ground one on top of the other have had to serve, even these being occasionally removed and stolen.

It was decided that the traverse for detail survey on the scale 64 inches to 1 mile in Allahābād city should be undertaken first as being the more important, and this was commenced in March 1921 under Mr. Mohammad Husain, Sub-Assistant Superintendent, with 4 traversers, after completion of the party's own programme of traverse survey for its normal topographical work. This avoided the uneconomical arrangement of dividing the available traversers into two separate and far-distant camps and also allowed time for the iron pegs for traverse stations to be manufactured.

A preliminary reconnaissance was carried out by Mr. Muhammad Husain before the normal work of the party was completed and a line of traverse was brought along the railway line from Birua Tower Station of the Gurwāni Meridional series and connected to the old traverse station to check the old traverse data.

The traverse of the city proper was divided into 4 blocks which together covered an area of 4128 acres. Each block was further sub-divided into numerous sub-traverses of from 18 to 30 acres in area according to the density of the population.

The traverse of *Block No. 1* was initiated at the junction of the Grand Trunk and Karela Bagh roads and was carried south along the latter to the southern limit of the city area. Proceeding eastward from this point it joined the left bank of the Jumna river at the Kakaria Ghāt and was taken thence by the bank of the river and southern municipal boundary to the Jumna road and along this to its junction with Lowther road. Thence the line was carried northwards along the latter to the railway bridge crossing the Grand Trunk road where it turned west and was closed on its initial starting point.

The traverse of *Block No. 2* was commenced from the Fort Cantonment boundary pillar No. 1 and being carried eastwards to the south-east corner of Kydeganj and thence northwards was run along the municipal limit inside the cantonment boundary up to the junction of the Canning and Grand Trunk roads. Thence the traverse turned westwards along Canning road, the northern boundary of the area, to its junction with Lowther road and being carried southwards along Lowther road where it joined with Block No. 1 and eastwards along the Jumna Bank road was closed on its starting point at pillar No. 1.

The traverse of *Block No. 3* was taken off from block No. 2 at the junction of Lowther and Canning roads and carried westwards along the latter and thence along the Cawnpore road, which two roads here form the northern limit of the city area, to Cantonment boundary pillar No. 1 from whence the line runs south and thence east along Station road and is closed on the initial starting point of block No. 1.

The traverse of *Block No. 4* was started from cantonment boundary pillar No. 1 of block No. 3 and proceeded westwards along the railway, which here also forms the cantonment boundary up to the furthest and most western municipal limit where it turned southwards to the south-west corner of Beniganj. Thence it was taken eastwards along the southern boundary of the Nawa Purwa Kareli area and closed with block No. 1 on the Karela Bagh road.

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The *sub-traverses* of blocks covered practically every street and road within the area. A very large number of off-sets was taken.

The *instruments used* were two 6-inch and two 5-inch theodolites by Messrs. Troughton and Simms reading to 10 seconds and 20 seconds respectively.

For *method* particular care was taken to centre the theodolite accurately over each traverse station. Two measures of each angle were taken.

The cantonment boundary pillars were made stations of observation where convenient but were otherwise measured by off-set or intersected by the theodolite.

Traverse signals.—Four traverse tripods of the pattern used by the Ordnance Survey of England were specially made for this work by the Mathematical Instrument Office at Calcutta, but they were found difficult to adjust easily and quickly and after a trial their use was abandoned in favour of the much quicker and easier signal of an ordinary large sized needle which was held over the mark and brought to a vertical position by the aid of the vertical wire of the theodolite. Only the very flat nature of the ground and the fact that no heights were required permitted the use of this signal and no disparagement of the traverse tripod is intended.

Measurements were taken with 100-foot and 66-foot steel tapes 1/3rd and 1/5th of an inch wide respectively wound on a small metal drum about 6 inches in diameter, and graduated to feet along the whole length. Measurements with the 100-foot tape were checked by those with the 66-foot tape. The tape was carefully aligned along the ground from one peg to another until the next traverse station was reached where the measurement was read to the last complete foot and the remainder recorded to 1/10th of a foot.

Off-sets were measured with 100-foot tapes similar to the above. The tapes were compared daily during the survey with the standard steel tape.

The *computation* was carried out *pari passu* with the traverse in the field by 3 computers and has been done on the revenue system, the proving and balancing of error being done separately for each block by which the accumulation of error is much reduced.

As many as possible of the permanent stations of the old traverse were picked up, but the large correction applied in the old data has not been accepted.

During *recess* the computation was completed together with the working out of the co-ordinates on the system of first in the series as origin and the preparation of 78 plot charts on the scale of survey (64 inches to 1 mile). These were handed over to the Chief Engineer to the Trust on the 11th August who came to recess quarters to receive them.

The out-turn of traversing was 128·94 linear miles in the area of 4,128 acres (6·45 square miles), while the number of stations at which the theodolites were set up was 2,259.

The average angular error of the traverse is 4 seconds and the linear error per 1000 feet is 0·16.

The traversing of the remaining areas for both the 64-inch and 16-inch scales of approximately 2 and 11 square miles respectively will be completed during the ensuing field season 1921-22.

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SETTLEMENT OF THE BOUNDARY BETWEEN MYSORE STATE AND THE SOUTH KANARA DISTRICT OF THE MADRAS PRESIDENCY.

By J. O'B. Donaghey.

On the 1st January 1921, the following officers were deputed for the final settlement of the Mysore-South Kanara boundary:—

Mr. T. Hanumantha Rau, representing the Mysore Darbār.
„ K. Raman Nayar, „ „ Madras Government.
„ J. O'B. Donaghey, Survey of India officer.

The work for the Survey officer was to determine the position of the line as previously fixed and described by boundary commissioners in 1880-81 and 1904-06.

Field work was commenced on the 19th February 1921 and about 24 miles of boundary were finally settled. Owing to bad weather which set in early in April 1921, field work was closed towards the end of the month. With the approval of the Madras Government and the Mysore Darbār, the work will be completed during the next field season.

The demarcation work was carried out by the erection of cairns and a clearing where necessary along the boundary line. A survey record of the boundary was prepared on sheets of the Madras forest survey on the 4-inch scale and a descriptive memorandum of the line was kept up. Considerable difficulties were experienced as regards labour and some very heavy jungle clearing was necessary along a section of the boundary which ran in a straight line from one hill top to another across most difficult and heavily wooded country.

The Survey establishment consisted of one surveyor and 15 menials.

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APPENDIX

List of Survey of India Publications

(Corrected up to 30th September 1921)

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PUBLICATIONS

OF THE

SURVEY OF INDIA

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A—HISTORY AND GENERAL REPORTS.

(*Obtainable from the Superintendent, Map Publication, 13, Wood Street, Calcutta*).

MEMOIRS.

1. A Memoir on the Indian Surveys. *By C. R. Markham,* India Office, London, 1871. *Price Rs. 5 or 10s.*
2. Ditto (second edition). *By C. R. Markham, C.B., F.R.S.,* India Office, London, 1878. *Price Rs. 5-8 or 11s.*
3. Abstract of the Reports of the Surveys and of other Geographical Operations in India, 1869-78. *By C. R. Markham and C. E. D. Black,* India Office, London. Published annually between 1871 and 1879. (Out of print).
4. A Memoir on the Indian Surveys, 1875-1890. *By C.E.D. Black,* India Office, London, 1891. *Price Rs. 5-8 or 11s.*

ANNUAL REPORTS.

Reports of the **Revenue Branch.** 1851-1877.—(1851-67 and 1869-70, out of print). *Price Rs. 3 or 6s.*

Ditto **Topographical Branch** 1860-1877.—(Out of print).

Ditto **Trigonometrical Branch.** 1861-1878.—(1861-71, out of print). *Price Rs. 2 or 4s.*

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, are available as follows:—

General Reports { from 1877-1900 (1877-79, 1887-88, 1895-96 and 1897-98, out of print) *at Rs. 3 or 6s per volume.*
{ from 1900-1921 (1902-04 and 1906-08, out of print) *at Rs. 2 or 4s per volume.*

From 1900 onwards the Report has been issued annually in the form of a condensed statement known as the **"General Report"** supplemented by fuller reports, which were called **"Extracts from Narrative Reports"** up to 1909, and since then have been styled **"Records of the Survey of India."** These fuller reports are available as follows:—

(*a*) **"Extracts" Volumes** *at Rs. 1-8 or 3s per volume.*

1900-01—Recent Improvements in Photo-Zincography. G. T. Triangulation in Upper Burma. Latitude Operations. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02—G. T. Triangulation in Upper Burma. Latitude Operations. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904. (Out of print.)

1902-03—Principal Triangulation in Upper Burma. Topography in Upper Burma. Topography in Shan States. Survey of Sāmbhar Lake. Latitude Operations. Tidal and Levelling. Magnetic Survey. Introduction of the Contract System of Payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thāna Maps. Calcutta, 1905.

1903-04—Magnetic Survey. Pendulum. Tidal and Levelling. Astronomical Azimuths. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906.

1904-05—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Survey Operations with the Somāliland Field Force. Calcutta, 1907.

1905-06—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography in Shan States. Calcutta, 1908.

1906-07—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909.

1907-08—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography in Shan States. Calcutta, 1910.

1908-09—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911.

(*b*) **"Records of the Survey of India"** *at Rs. 4 or 8s per volume, except where otherwise stated.*

Vol. I—**1909-10**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey (Astronomical latitudes and pendulum observations). Magnetic Survey. ... ... Calcutta, 1912.

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ANNUAL REPORTS—(*Continued*).

Vol. II—**1910-11**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. ... ... Calcutta, 1912.

III—**1911-12**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey, Magnetic Survey. ... ... Calcutta, 1913.

IV—**1911-13**—*Explorations on the North-East Frontier—North Burma, Mishmi, Abor and Miri Surveys* ... ... Calcutta, 1914.

V—**1912-13**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. Note on the relationship of the Himālayas to the Indo-Gangetic Plain. ... ... Calcutta, 1914.

VI—**1912-13**—*Link connecting the Triangulations of India and Russia* Dehra Dūn, 1914.

VII—**1913-14**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey (Annual report and Government Committee's report). Note on Scales and cost rates of Town plans. Calcutta, 1915.

VIII—{**1865-79—Part I**} *Explorations in Tibet and neighbouring regions* { Dehra Dūn, 1915. *Price of each part Rs. 4 or 8s.*
{**1879-92—Part II**}

IX—**1914-15**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Magnetic Survey. Criterion of strength of Indian Geodetic Triangulation. A traverse signal for City Surveys. The plains of Northern India and their relationship to the Himālaya Mountains by Colonel S. G. Burrard F. R. S. Report on Turco-Persian Frontier Commission. Calcutta, 1916.

X—**1915-16**—Topographical Survey. Tidal and Levelling Operations. Magnetic Survey. Mechanical Integrator for calculating Attractions (illustrated). Traverse Survey of the boundary of Imperial Delhi ... Dehra Dūn, 1917.

XI—**1916-17**—Topographical Survey. Triangulation—use of high trestle for stations and 100-feet mast signals. Tidal and Levelling Operations. Magnetic Survey. Note on Basevi's Pendulum perations at Morē. Photo-Litho Office—New method of preparing Layer plates—Developments and Improvements in preparing Tint-plates. Dehra Dūn, 1918.

XII—Notes on Survey of India Maps and the modern development of Indian Cartography. *By Lt.-Col. W.M. Coldstream, R.E., Superintendent, Map Publication.* } Calcutta, 1919. *Price Rs. 3 or 6s.*

XIII—**1917-18**—Topographical Survey. Tidal and Levelling Operations. Magnetic Survey. Photo-Litho office—the Powder Process. Problem of the Himālayan and Gangetic Trough—Review by Dr. A. Morley Davies. Dehra Dūn, 1919.

XIV—**1918-19**—Topographical Survey. Tidal and Levelling Operations. Levelling in Mesopotamia. Magnetic Survey. ... ... Dehra Dūn, 1920.

XV—**1919-20**—Topographical Survey. Tidal work. Levelling—proposed new level net. Magnetic Survey. The Earth's Axes and Figure by Dr. J. de Graaff Hunter (a paper read at the R. A. S. Geophysical Meeting). Report on the expedition to Kamet. Note on the Topography of the Nun Kun Massif in Ladākh ... ... Dehra Dūn, 1921

XVI—**1920-21**—Topographical Survey. Tidal work. Levelling and Magnetic Survey. High Climbs in the Himālaya prior to the Everest Expedition. Mt. Everest Survey Detachment Report, 1921. Traverse Survey of Allahābād city. Settlement of Boundary between Mysore and South Kanara. Dehra Dūn, 1922.

"Notes of the Survey of India" are issued monthly. (Stocked in the Surveyor General's Office, Calcutta). *Price as 2 or 3d.*

B—GEODETIC WORKS OF REFERENCE.

(Obtainable from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U.P.)

EVEREST'S GREAT ARC BOOK.

1. An account of the Measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′. *By Capt. George Everest.* East India Company, London, 1830. (Out of print).

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″, 24° 7′ 11″ and 29° 30′ 48″. *By Lt.-Col. G. Everest, F. R. S.* East India Company, London, 1847. (Out of print).

3. Engravings to illustrate the above. London, 1847. (Out of print).

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G.T.S. VOLUMES—describing the Operations of the Great Trigonometrical Survey.
Price Rs. 10-8 or 21s per volume, except where otherwise stated.

Vol. I—**Standards of Measure and Base-Lines,** also an Introductory Account of the early Operations of the Survey, during the period of 1800-1830.
Dehra Dūn, 1870. (Out of print).

Appendix No. 1. Description of the method of comparing, and the apparatus employed.
Appendix No. 2. Comparisons of the Lengths of 10-feet Standards **A** and **B**, and determinations of the Difference of their Expansions.
Appendix No. 3. Comparisons between the 10-feet Standards I_B I_S and **A**.
Appendix No. 4. Comparisons of the 6-inch Brass Scales of the Compensated Microscopes.
Appendix No. 5. Determination of the Length of the Inch [7.8] on Cary's 3-foot Brass Scale.
Appendix No. 6. Comparisons between the 10-feet Standard Bars I_S and **A** for determining the Expansion of bar **A**.
Appendix No. 7. Final determination of the Differences in Length between the 10-feet Standards I_B I_S and **A**.
Appendix No. 8. On the Thermometers employed with the Standards of Length.
Appendix No. 9. Determination of the Lengths of the Sub-divisions of the Inch [*a.b*].
Appendix No. 10. Report on the Practical Errors of the Measurement of the Cape Comorin Base.

II—**A History and General Description of the Reduction** of the Principal Triangulation. ... Dehra Dūn, 1879. (Out of print).

Appendix No. 1. Investigations applying to the Indian Geodesy.
Appendix No. 2. The Micrometer Microscope Theodolites.
Appendix No. 3. On Observations of Terrestrial Refraction at certain stations situated on the plains of the Punjab.
Appendix No. 4. On the Periodic Errors of Graduated Circles, &c.
Appendix No. 5. On certain Modifications of Colonel Everest's System of Observing introduced to meet the specialities of particular instruments.
Appendix No. 6. On Tidal Observations at Karāchi in 1855.
Appendix No. 7. An alternative Method of obtaining the Formulæ in Chapters VIII and XV employed in the Reduction of Triangulation.—Additional Formulæ and Demonstrations.
Appendix No. 8. On the Dispersion of Circuit Errors of Triangulation after the Angles have been corrected for Figural conditions.
Appendix No. 9. Corrections to azimuthal Observations for imperfect Instrumental Adjustments.
Appendix No. 10. Reduction of the N.W. Quadrilateral—the Non-Circuit Triangles and their Final Figural Adjustments.
Appendix No. 11. The Theoretical Errors of the Triangulation of the North-West Quadrilateral.
Appendix No. 12. Simultaneous Reduction of the N.W. Quadrilateral—the Computations.

III—**North-West Quadrilateral.**—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N. W. Himālaya, and the Great Indus Series. ... ... Dehra Dūn, 1873. (Out of print.)

IV—**North-West Quadrilateral**—The Principal Triangulation, the Great Arc—Section 24°-30°, Rahūn, Gurhāgarh and Jogi-Tīla Meridional Series and the Sutlej Series. ... ... Dehra Dūn, 1876.

IVA—**North-West Quadrilateral**—The Principal Triangulation, the Jodhpur and the Eastern Sind Meridional Series with the details of their Reduction and the Final Results. ... ... Dehra Dūn, 1886.

V—**Pendulum Operations** of Captains J. P. Basevi and W. J. Heaviside, and their Reduction. Dehra Dūn and Calcutta, 1879.

Appendix No. 1. Account of the Remeasurement of the Length of Kater's Pendulum at the Ordnance Survey Office, Southampton.
Appendix No. 2. On the Relation between the Indian Pendulum Operations, and those which have been conducted elsewhere.
Appendix No. 3. On the Theory, Use and History of the Convertible Pendulum.
Appendix No. 4. On the Length of the Seconds Pendulum determinable from Materials now existing.
Appendix No. 5. A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

VI—**South-East Quadrilateral**—The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc—Section 18° to 24°, the East Coast, the Calcutta and the Bīdar Longitudinal, the Jubbulpore and the Bilāspur Meridionals. ... ... Dehra Dūn, 1880. (Out of print.)

VII—**North-East Quadrilateral**—General Description and Simultaneous Reduction. Also details of the following five series:—North-East Longitudinal, the Budhon Meridional, the Rangir Meridional, the Amua Meridional, and the Karāra Meridional. ... ... Dehra Dūn, 1882.

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Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of several Chains of Triangles.

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X—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. Dehra Dūn, 1887.

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4. On the Rejection of some doubtful Arcs of Season 1881-82.
5. On the probable Causes of the Errors of Arc-measurements, and on the Nature of the Defects in the Transit Instruments which might produce them.

XI—**Astronomical Latitudes**—during the period 1805-1885. Dehra Dūn, 1890.

XII—**Southern Trigon**—General Description and Simultaneous Reduction. Also details of the following two series:—Great Arc—Section 8°-18°, and Bombay Longitudinal. ... ... Dehra Dūn, 1890.

XIII—**Southern Trigon**—Details of the following five series:—South Konkan Coast, Mangalore Meridional, Madras Meridional and Coast, South-East Coast, and Madras Longitudinal. ... ... Dehra Dūn, 1890.

XIV—**South-West Quadrilateral**—Details of Principal Triangulation and Simultaneous Reduction of its component series. ... Dehra Dūn, 1890.

XV—**Telegraphic Longitudes**—from 1885 to 1892 and the Revised Results of Volumes IX and X: also the Simultaneous Reduction and Final Results of the whole Operations. ... ... Dehra Dūn, 1893.

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XVI—**Tidal observations**—from 1873 to 1892, and the Methods of Reduction. Dehra Dūn, 1901.

XVII—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. .. ... Dehra Dūn, 1901.

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VI—The Jogi-Tīla Meridional Series (*37*). and the Sutlej Meridional Series (*45*). Dehra Dūn, 1875.

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South-East Quadrilateral

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X—The Bīdar Longitudinal Series (*43*). Dehra Dūn, 1880.

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XII—The Calcutta Longitudinal Series (*5*). Dehra Dūn, 1880

XIII—The East Coast Series (*24*). Dehra Dūn, 1880.

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„	**35**	24°–28°	64°–68°	„	1911.	„	„	Addendum		„	1920.
„	**38**	32°–36°	68°–72°	„	1912.	„	**64**	20°–24°	80°–84°	„	1912.
„	**39**	28°–32°	68°–72°	„	1913.	„	**65**	16°–20°	80°–84°	„	1913.
„	„	Addendum		„	1916.	„	**66**	12°–16°	80°–84°	„	1912.
„	**40**	24°–28°	68°–72°	„	1911.	„	**72**	24°–28°	84°–88°	„	1912.
„	**41**	20°–24°	68°–72°	„	1913.	„	„	Addendum		„	1920.
„	**43**	32°–36°	72°–76°	„	1913.	„	**73**	20°–24°	84°–88°	„	1913.
„	„	Addendum		„	1915.	„	„	Addendum		„	1920.
„	**44**	28°–32°	72°–76°	„	1920†.	„	**74**	16°–20°	84°–88°	„	1913.
„	„	Addendum		„	1921.	„	**78**	24°–28°	88°–92°	„	1912.
„	**45**	24°–28°	72°–76°	„	1911.	„	„	*Addendum		„	1916.
„	**46**	20°–24°	72°–76°	„	1912.	„	**79**	20°–24°	88°–92°	„	1912.
„	**47**	16°–20°	72°–76°	„	1912.	„	„	Addendum		„	1916.
„	„	*Addendum		„	1915.	„	**83**	24°–28°	92°–96°	„	1912.§
„	**48**	12°–16°	72°–76°	„	1912.						
„	**49***	8°–12°	72°–76°	„	1911.	Burma	**84**	20°–24°	92°–96°	„	1918.‖
„	**52**	32°–36°	76°–80°	„	1912.						
„	**53**	28°–32°	76°–80°	„	1920.	„	**85**	16°–20°	92°–96°	„	1917.‖
„	**54**	24°–28°	76°–80°	„	1921.¶	„	**92**	24°–28°	96°–100°	„	1918.‖
„	**55**	20°–24°	76°–80°	„	1912.	„	**93**	20°–24°	96°–100°	„	1917.‖
„	**56**	16°–20°	76°–80°	„	1912.	„	**94**	16°–20°	96°–100°		
„	*Addendum			„	1919.					„	1916.‖
„	**57**	12°–16°	76°–80°	„	1919.‡	„	**95**	12°–16°	96°–100°		
„	**58**	8°–12°	76°–80°	„	1914.						

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TIDE TABLES—(*Continued*).

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4. * Map Publication Orders 1908-1914 (*Superintendent, Map Publication's Orders.*)—Calcutta, 1914.
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5. Catalogue of Books in the Head-Quarters Library, Calcutta, 1901. (Out of print).

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6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1 or 2s.*

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F	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*f*	*ac* 1918	*ac* 1916	*S*									*ac* 1919				*S*							*d* 1913										F
G	*ac* 1917	*ac* 1917	*S*			*ac* 1919	*f*	*bc* 1916	*ac* 1918	*ac* 1918	*S*			*d* 1913						*ac* 1919		*S*		*S*	*S*													*d* 1911				G
H	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*bc* 1916	*ac* 1918	*ac* 1918	*S*					*S*				*ac* 1919		*S*			*S*						*S*	*S*										H
I	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*f*	*ac* 1918	*ac* 1918	*ac* 1918									*ac* 1919		*d* 1913		*S*	*S*					*ac* 1921	*ac* 1921										I
J	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*f*	*ac* 1918	*ac* 1918	*S*									*ac* 1919			*S*	*S*	*S*																	J
K	*ac* 1917	*ac* 1917	*S*			*ac* 1919	*f*	*bc* 1916	*ac* 1918	*ac* 1918	*S*			*d* 1913						*ac* 1919			*S*	*S*																	K
L	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*bc* 1916	*ac* 1916	*ac* 1918	*S*			*d* 1913		*S*				*ac* 1919	*d* 1913		*S*	*S*	*S*				*ac* 1921													L
M	*ac* 1917	*ac* 1917	*S*			*f*	*f*	*f*	*ac* 1918	*ac* 1918	*S*				*bc* 1916					*ac* 1919				*S*	*S*					*bc* 1916											M
N	*ac* 1916	*ac* 1917	*S*			*f*	*f*	*f*	*ac* 1918	*ac* 1918	*S*				*bc* 1915					*ac* 1919			*S*	*S*	*S*				*d* 1912													N
O	*ac* 1916	*ac* 1917	*S*			*f*	*f*	*bc* 1916	*ac* 1918	*ac* 1918	*S*			*d* 1913						*ac* 1919			*S*	*S*	*S*																	O
P	*ac* 1917	*S*	*S*			*f*	*f*	*bc* 1916	*ac* 1916	*ac* 1918	*S*			*d* 1913	*d* 1912	*S*				*ac* 1919			S	*S*	*S*				*ac* 1921													P

a Pamphlet with G.T. data available at Trigonometrical Survey Office. *b* Pamphlet with G.T., if any, and Topo. data received from parties. *c* Data with chart.
d Data published in the old style (chart form). *f* No data available at Trigonometrical Survey Office. *S* Area falling in the sea. *A* Addendum in a separate pamphlet

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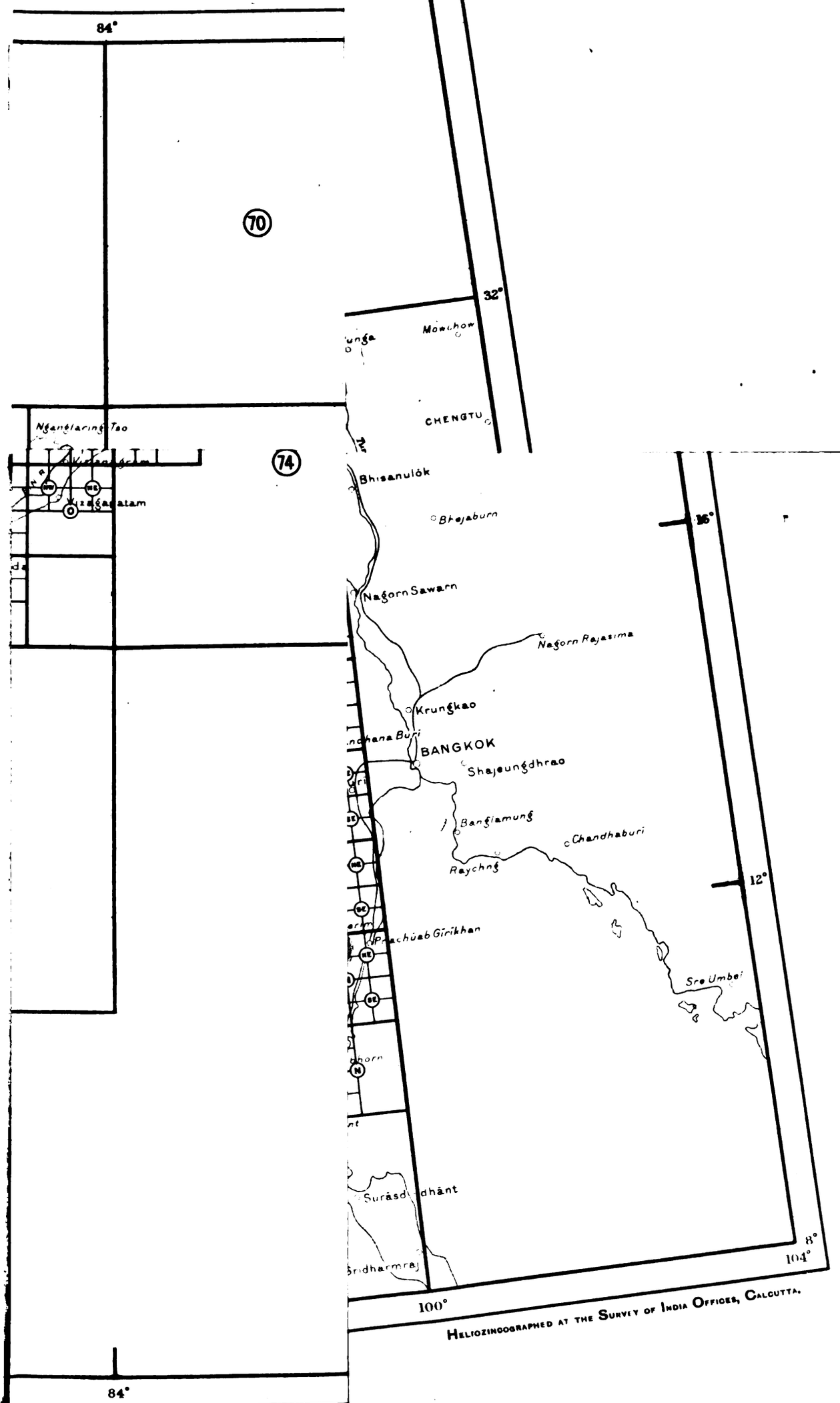
& PUBLICATIO 1

30TH SEPTEMBER, 1921.



HELIOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA.

onel C.H.D. Ryder, C.I.E., D.S.O., R.E., *Surveyor Ge*

1921.

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HALF INCH SERIES

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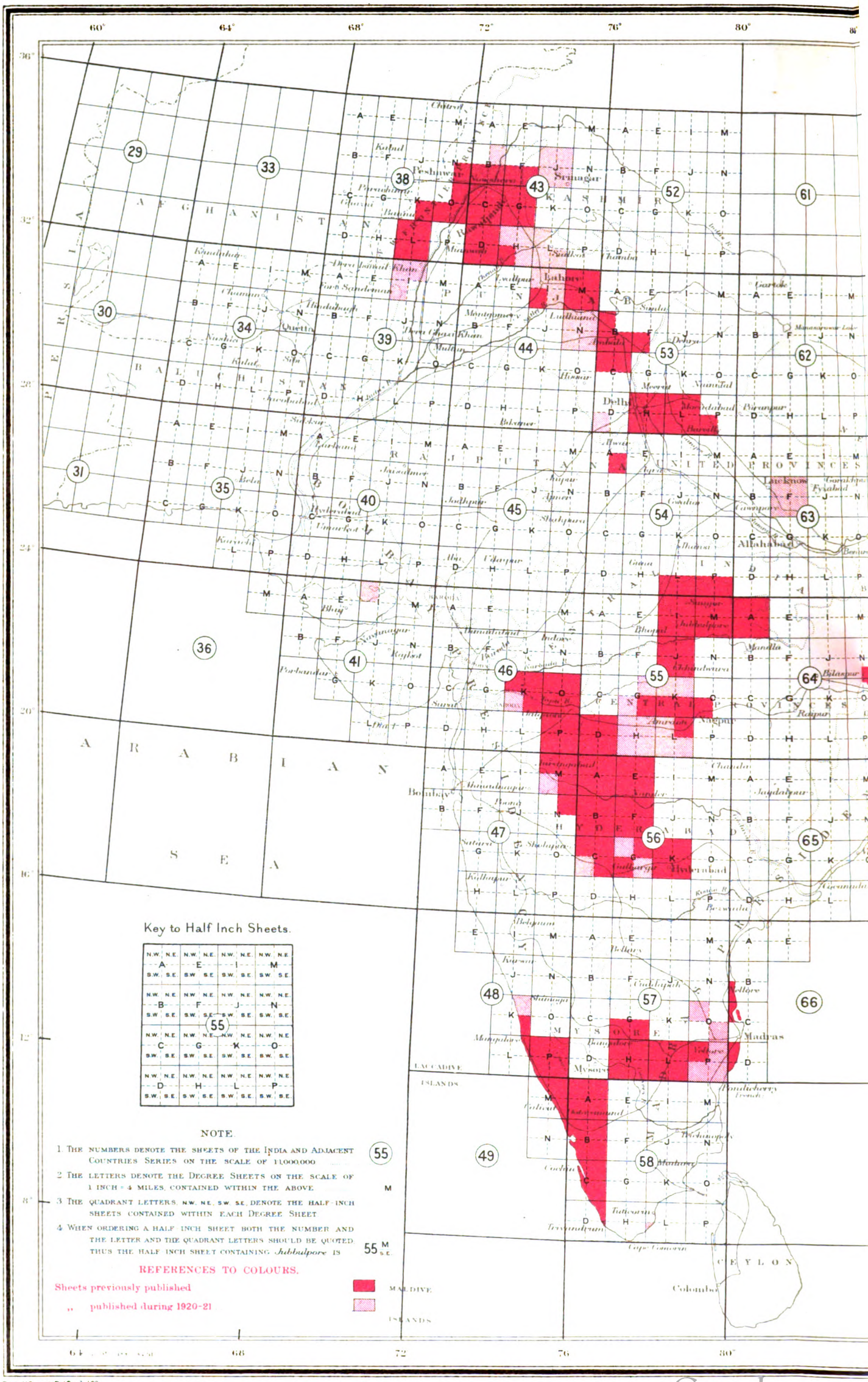

Reg. N° 3136 D 19—1.100

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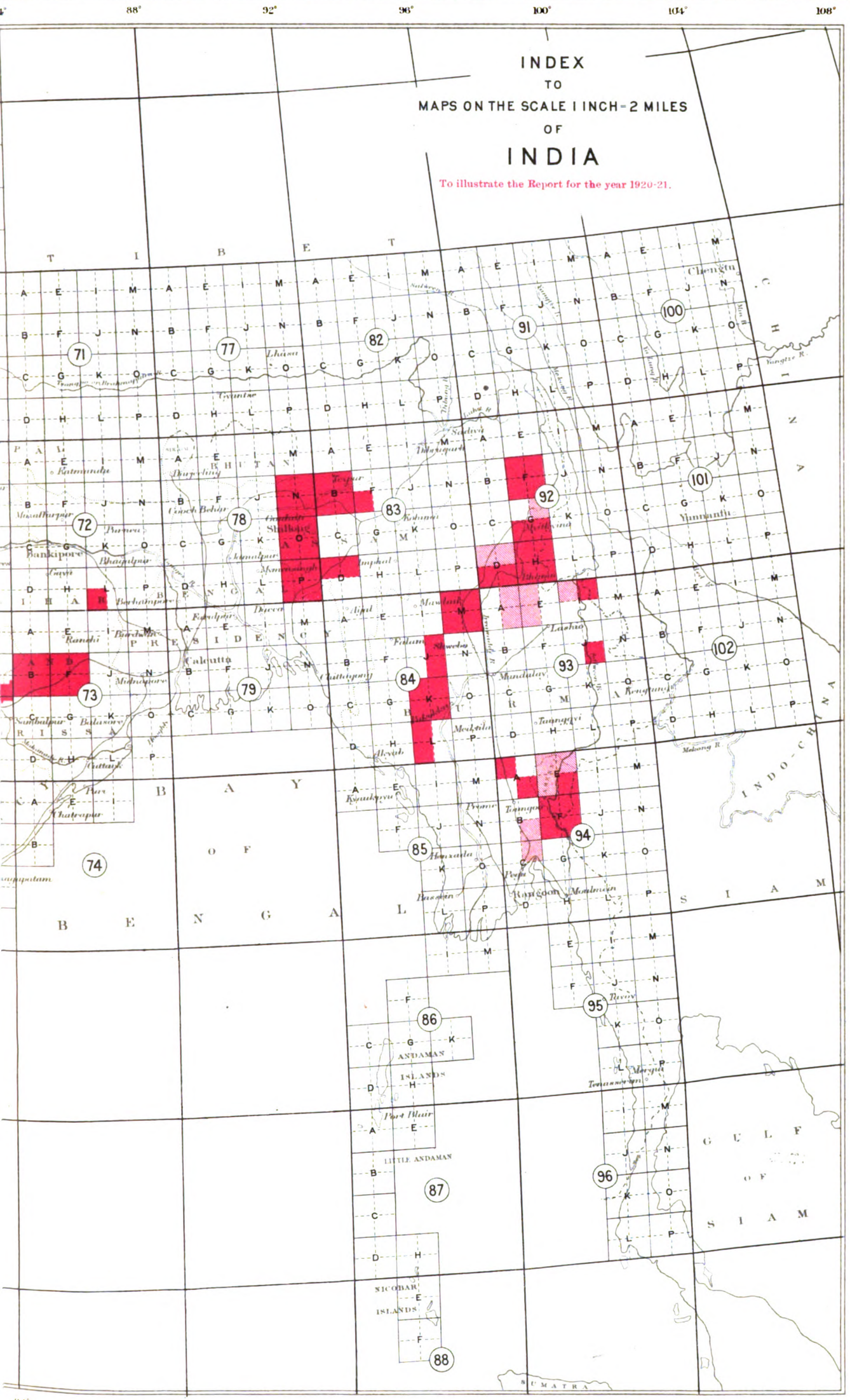
INDEX
TO
MAPS ON THE SCALE 1 INCH = 2 MILES
OF
INDIA

To illustrate the Report for the year 1920-21.



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DEGREE SHEET SERIES

Scale 1 Inch to 4 Miles.

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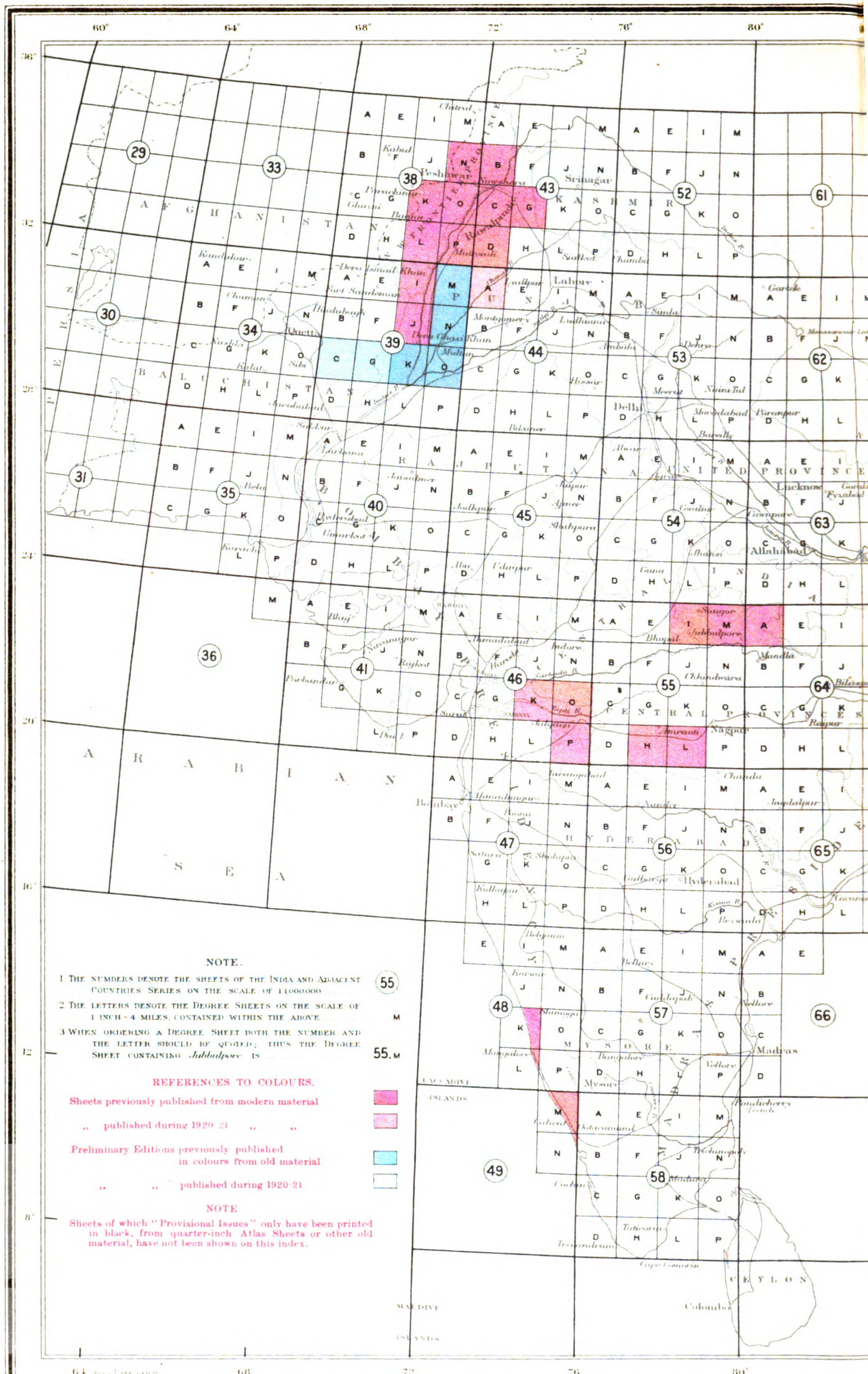

NOTE.

1. The numbers denote the sheets of the India and Adjacent Countries Series on the scale of 1:1000000 — 55

2. The letters denote the Degree Sheets on the scale of 1 inch = 4 miles, contained within the above — M

3. When ordering a Degree Sheet both the number and the letter should be quoted; thus the Degree Sheet containing *Jubbulpore* is — 55.M

REFERENCES TO COLOURS.

Sheets previously published from modern material

" published during 1920-21 " "

Preliminary Editions previously published in colours from old material

" " published during 1920-21

NOTE

Sheets of which "Provisional Issues" only have been printed in black, from quarter-inch Atlas Sheets or other old material, have not been shown on this index.

Reg. N° 3137 D 19.—1.100

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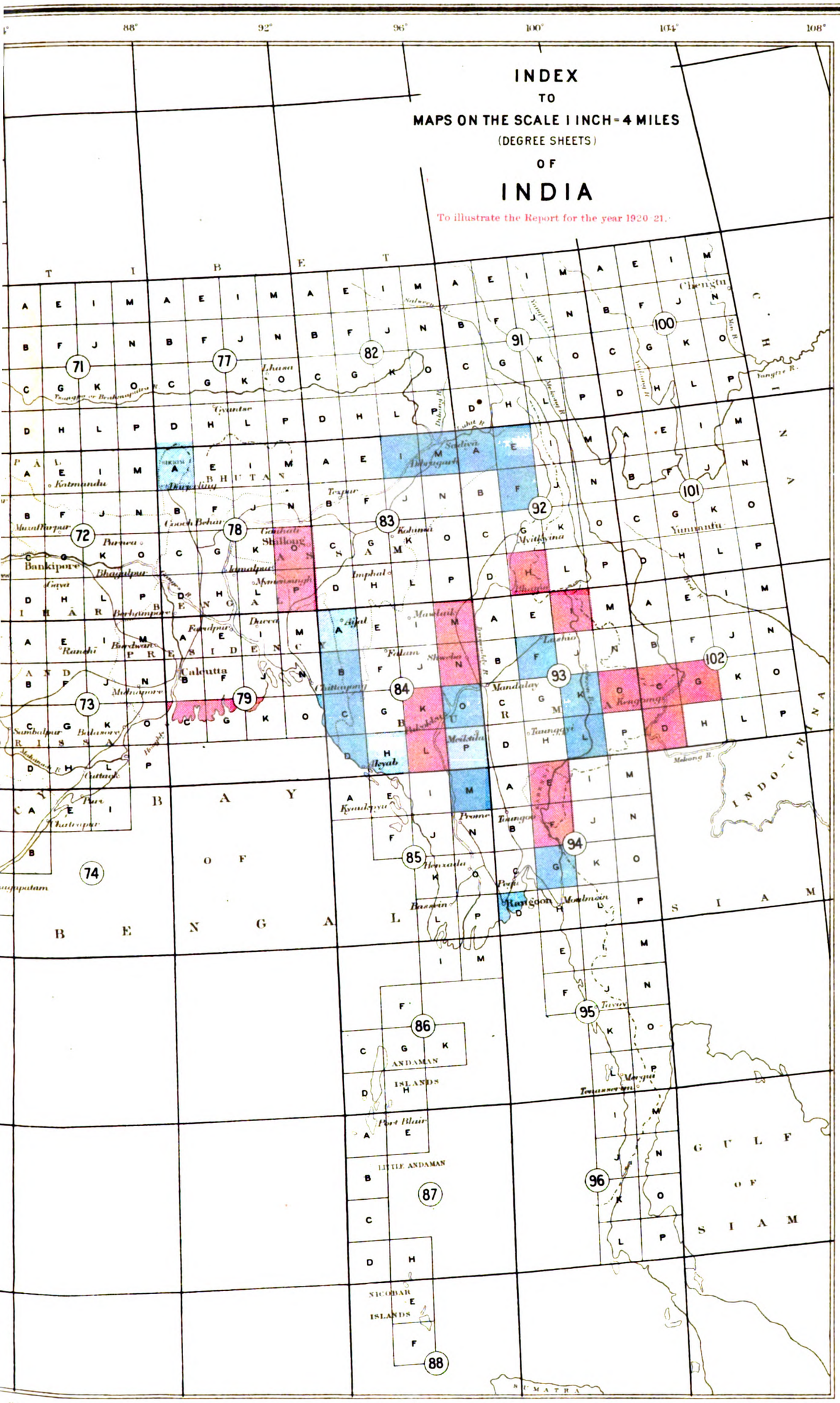
INDEX
TO
MAPS ON THE SCALE 1 INCH = 4 MILES
(DEGREE SHEETS)
OF
INDIA

To illustrate the Report for the year 1920-21.



ENGD & HELIO S I O, CALCUTTA.

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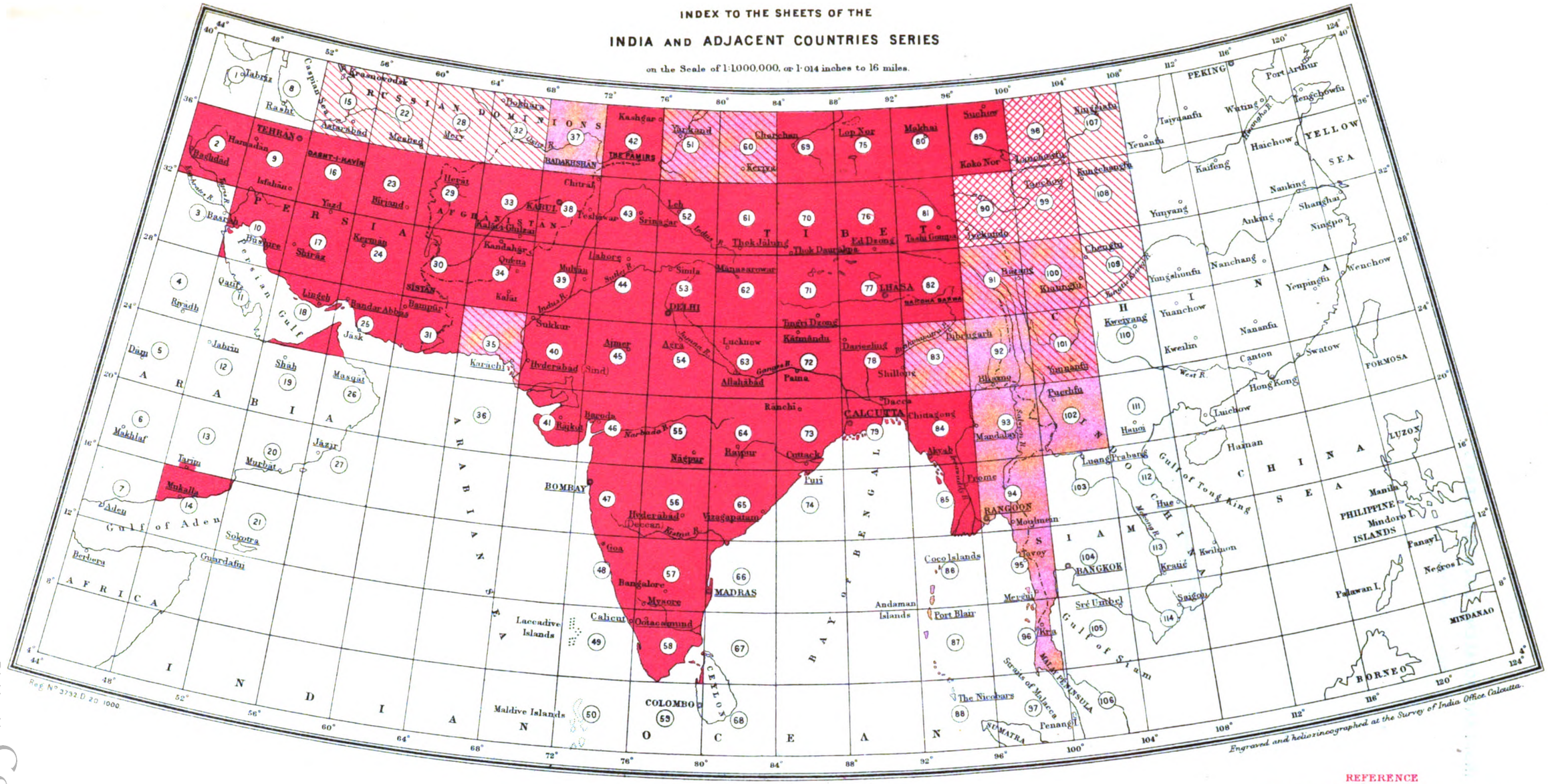
INDEX TO THE SHEETS OF THE

INDIA AND ADJACENT COUNTRIES SERIES

on the Scale of 1:1,000,000, or 1·014 inches to 16 miles.



Scale 1/6,000,000.

Miles 200 0 200 400 600 800 Miles.

NOTE.

The names underlined on this Index are the title names of the sheets, and their numbers are shown in circles. Sheets 35 and 36, 57 and 66, are published respectively as combined sheets.

Engraved and heliozincographed at the Survey of India Office, Calcutta.

Reg. N° 3732 D 20·1000.

REFERENCE

To illustrate the Report for the year 1920-21.

Sheets published without contours & layers

" " with contours & layers

" under publication

" in hand

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INDIA AND ADJACENT COUNTRIES SERIES

Scale 1: 1,000,000.

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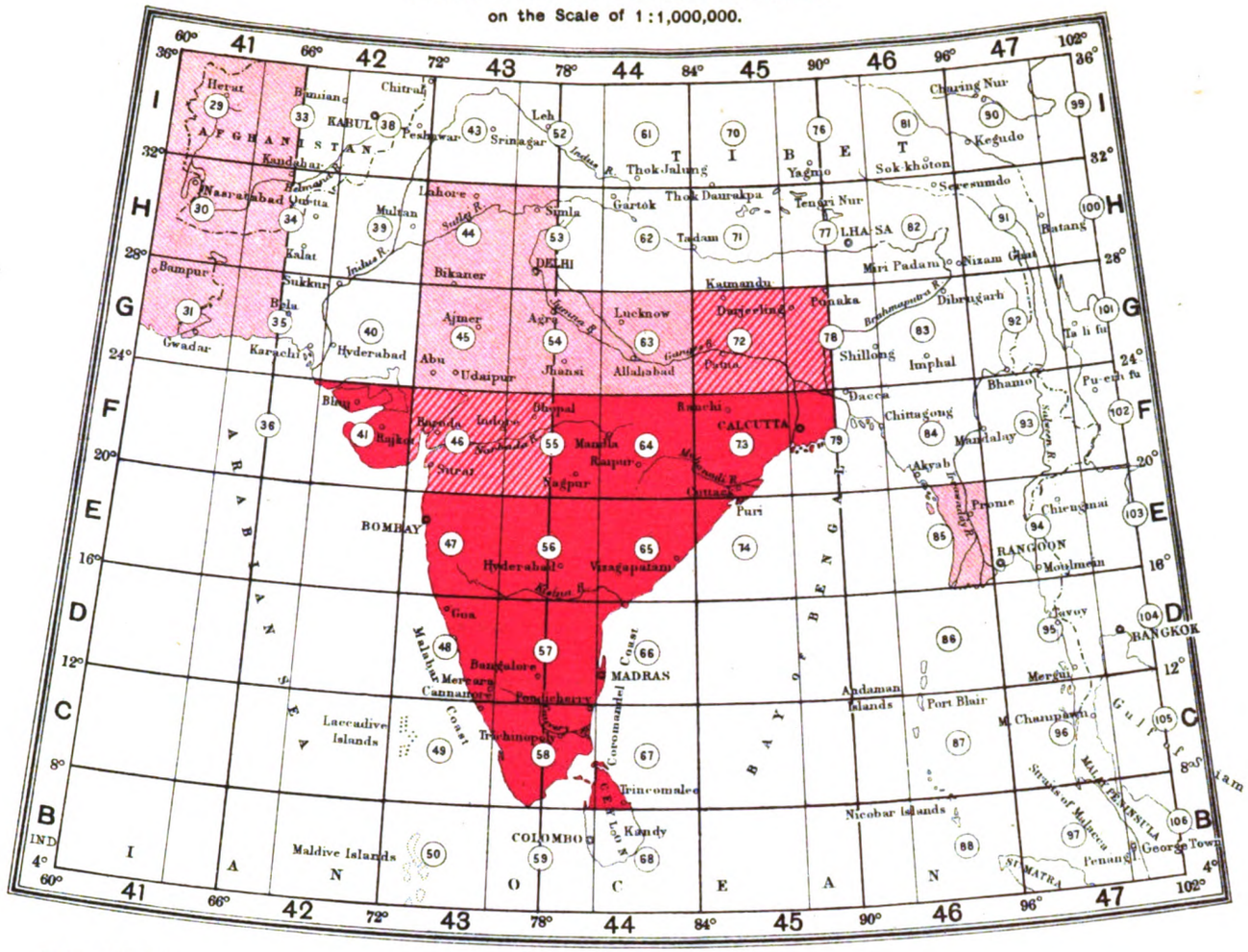
INDEX TO THE SHEETS OF THE CARTE INTERNATIONALE DU MONDE

on the Scale of 1 : 1,000,000.



EXPLANATION.

The thick lines show the margins of the sheets of the International Map of the World, Scale 1:1,000,000. Each sheet is designated by the letter N (Northern hemisphere), followed by the marginal letter and number corresponding to its position, *e.g.*, the sheet which includes Bombay is N.E-43.

The figures in circles are the numbers of the sheets of the India and Adjacent Countries Series on the Scale of 1:1,000,000.

Scale 1/1,000,000.

Miles 200 0 200 400 600 800 Miles

REFERENCE

Sheets published

" under publication

" in hand

To illustrate the Report for the year 1920-21.

Reg. No. 3441 D., 16. 1000

Helio., S. I. O., Calcutta.

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INTERNATIONAL SERIES

Scale 1:1,000,000.

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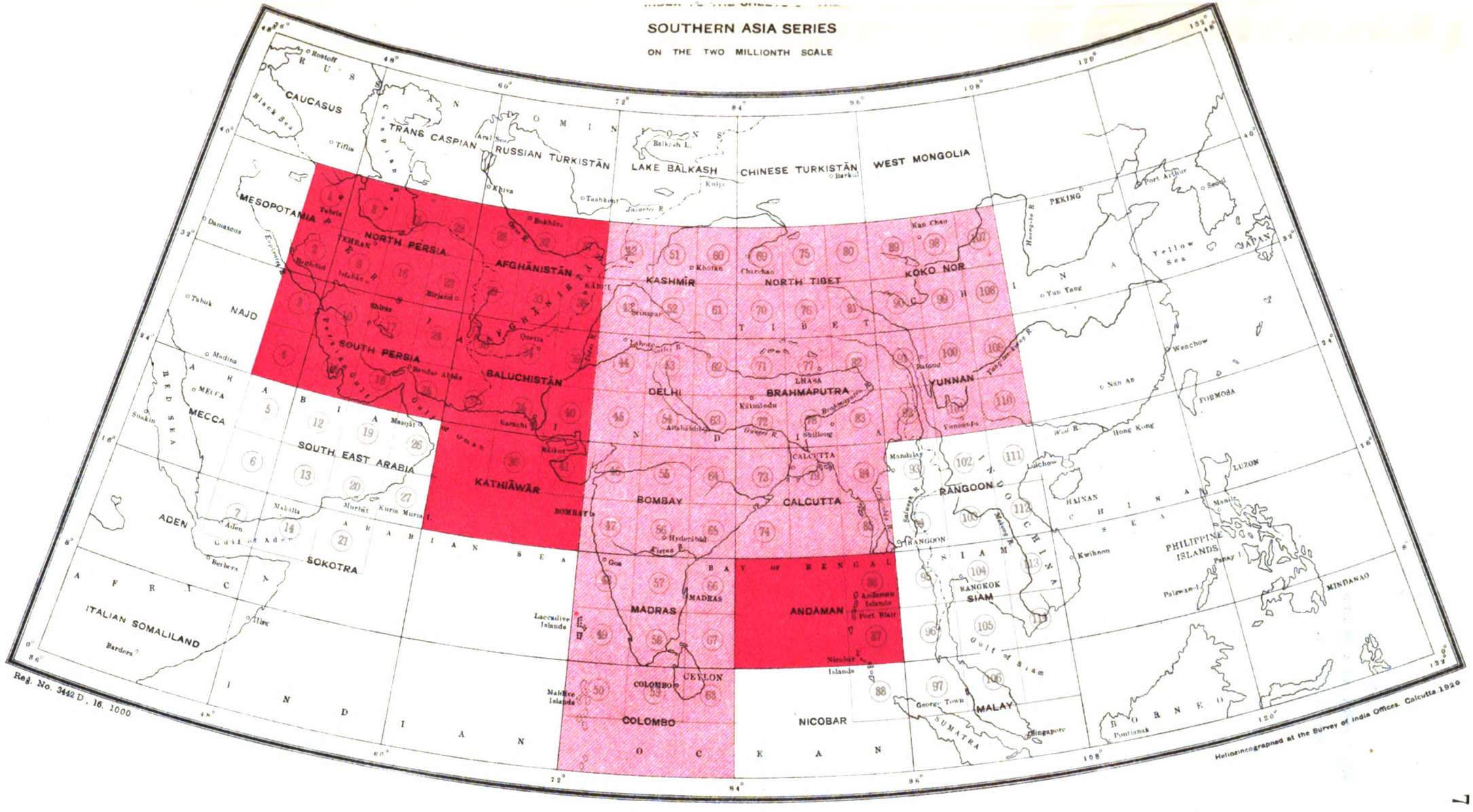
SOUTHERN ASIA SERIES

ON THE TWO MILLIONTH SCALE



Scale 1 / 40,000,000

Miles 200 0 200 400 600 800 1000 Miles

The E. portions of MESOPOTAMIA and NAJD sheets have been published for the present as outriggers to N. & S. PERSIA sheets respectively.

REFERENCE

To illustrate the Report for the year 1920-21.

Sheets published with contours & layers

" under publication

" in hand

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7

SOUTHERN ASIA SERIES

Scale 1:2,000,000.

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INDEX TO THE GREAT TRIGONOMETRICAL SURVEY

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9.

INDEX TO THE TRIANGULATION CHARTS AND PAMPHLETS.

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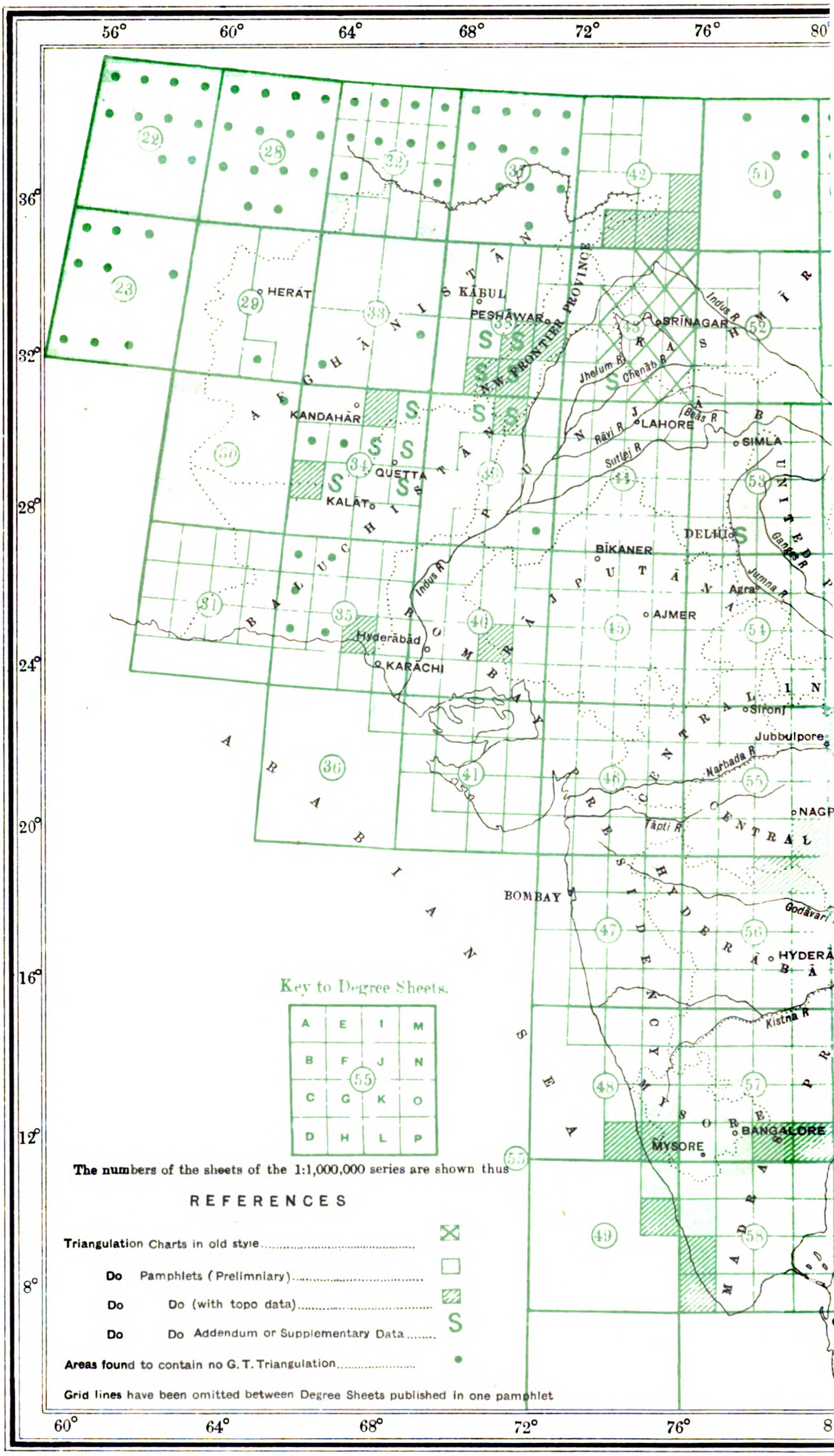

Reg. No. 1250 D.D.D. 1921 (2 D. O)-S. I.-400-22'350

Scale $\frac{1}{15,000,000}$ or 1·0

Miles 100 50 0 100

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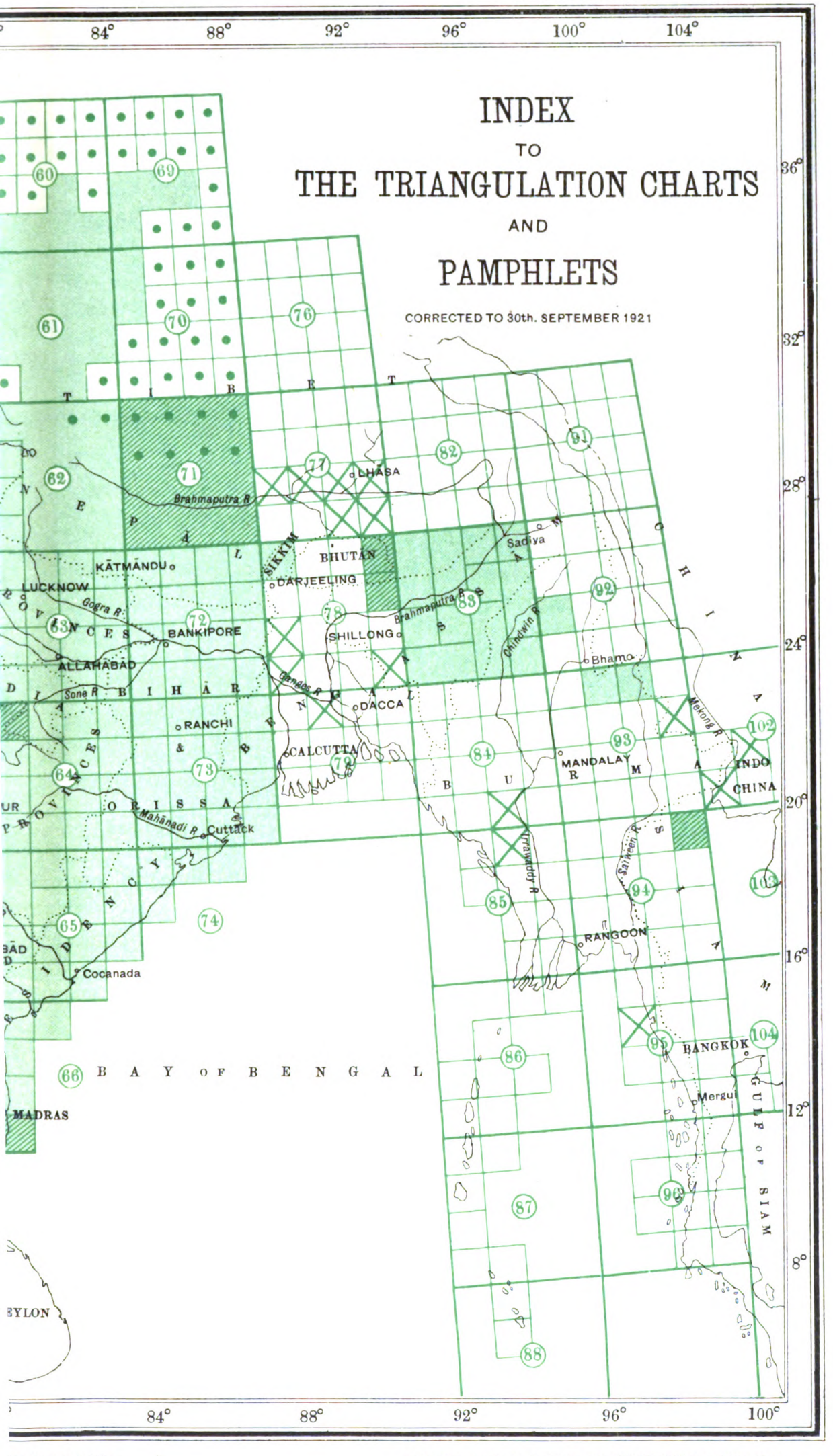

Inches to 240 Miles

300 400 500 Miles

Heliozincographed at the Survey of India Offices, Dehra Dun.

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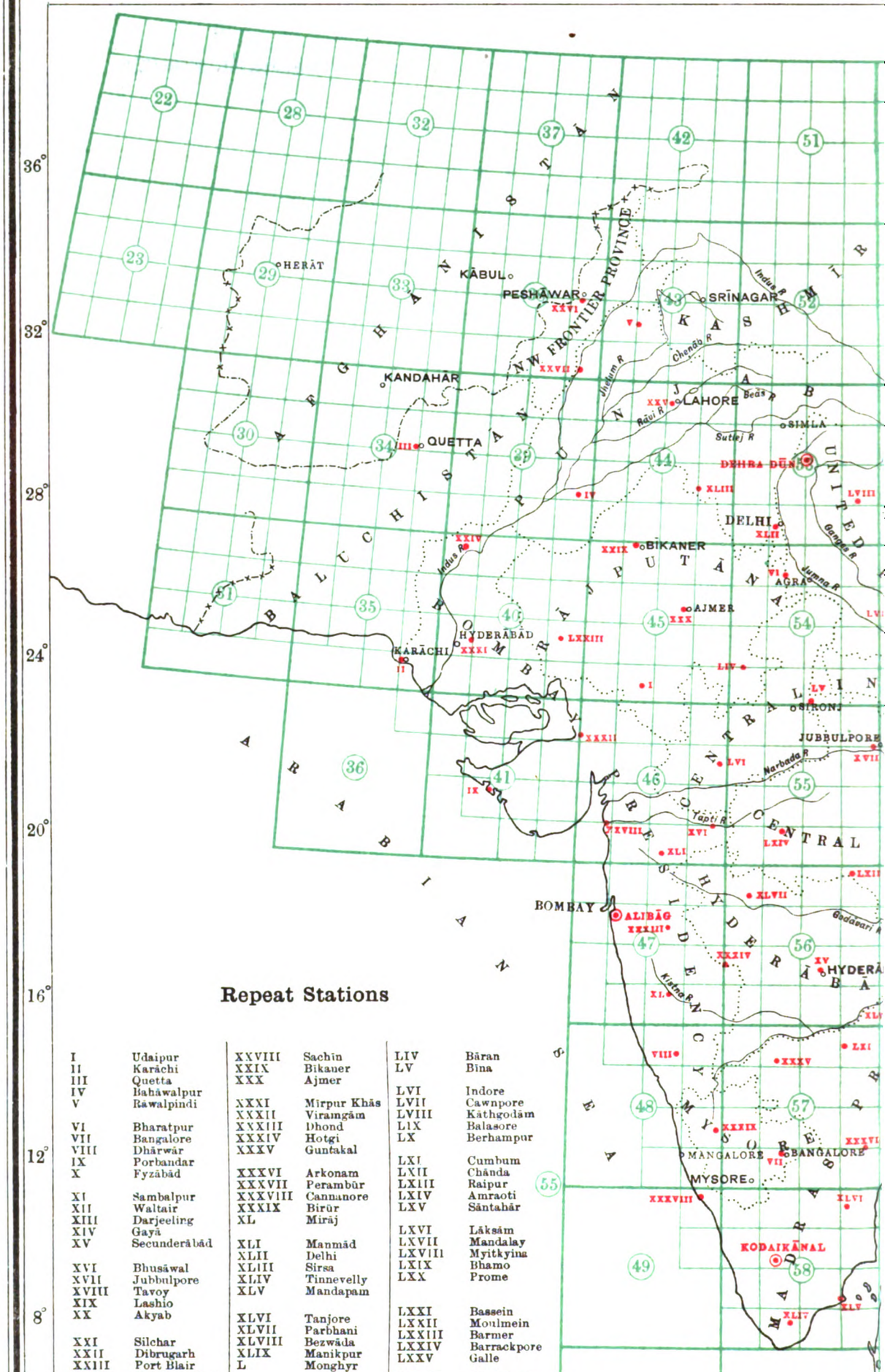

Repeat Stations

I	Udaipur	XXVIII	Sachīn	LIV	Bāran
II	Karāchi	XXIX	Bikaner	LV	Bīna
III	Quetta	XXX	Ajmer	LVI	Indore
IV	Bahāwalpur	XXXI	Mīrpur Khās	LVII	Cawnpore
V	Rāwalpindi	XXXII	Viramgām	LVIII	Kāthgodām
VI	Bharatpur	XXXIII	Dhond	LIX	Balasore
VII	Bangalore	XXXIV	Hotgi	LX	Berhampur
VIII	Dhārwār	XXXV	Guntakal	LXI	Cumbum
IX	Porbandar	XXXVI	Arkonam	LXII	Chānda
X	Fyzābād	XXXVII	Perambūr	LXIII	Raipur
XI	Sambalpur	XXXVIII	Cannanore	LXIV	Amraoti
XII	Waltair	XXXIX	Birūr	LXV	Sāntahār
XIII	Darjeeling	XL	Mirāj	LXVI	Lāksām
XIV	Gayā	XLI	Manmād	LXVII	Mandalay
XV	Secunderābād	XLII	Delhi	LXVIII	Myitkyina
XVI	Bhusāwal	XLIII	Sirsa	LXIX	Bhamo
XVII	Jubbulpore	XLIV	Tinnevelly	LXX	Prome
XVIII	Tavoy	XLV	Mandapam	LXXI	Bassein
XIX	Lashio	XLVI	Tanjore	LXXII	Moulmein
XX	Akyab	XLVII	Parbhani	LXXIII	Barmer
XXI	Silchar	XLVIII	Bezwāda	LXXIV	Barrackpore
XXII	Dibrugarh	XLIX	Manikpur	LXXV	Galle
XXIII	Port Blair	L	Monghyr	LXXVI	Phulchari
XXIV	Ruk Junction	LI	Sini	LXXVII	Palāsbāri
XXV	Lahore	LII	Katarnian Ghāt	LXXVIII	Kalaw
XXVI	Peshāwar	LIII	Bettiah	LXXIX	Kindat
XXVII	Kundiān			LXXX	Victoria Point

Reg. No. 1207 D.D.D. 1919 (2 D.O.) S.I.-400—400'20-400'22

Scale 1/15,000,000 or 1·0

Miles 100 50 0 100

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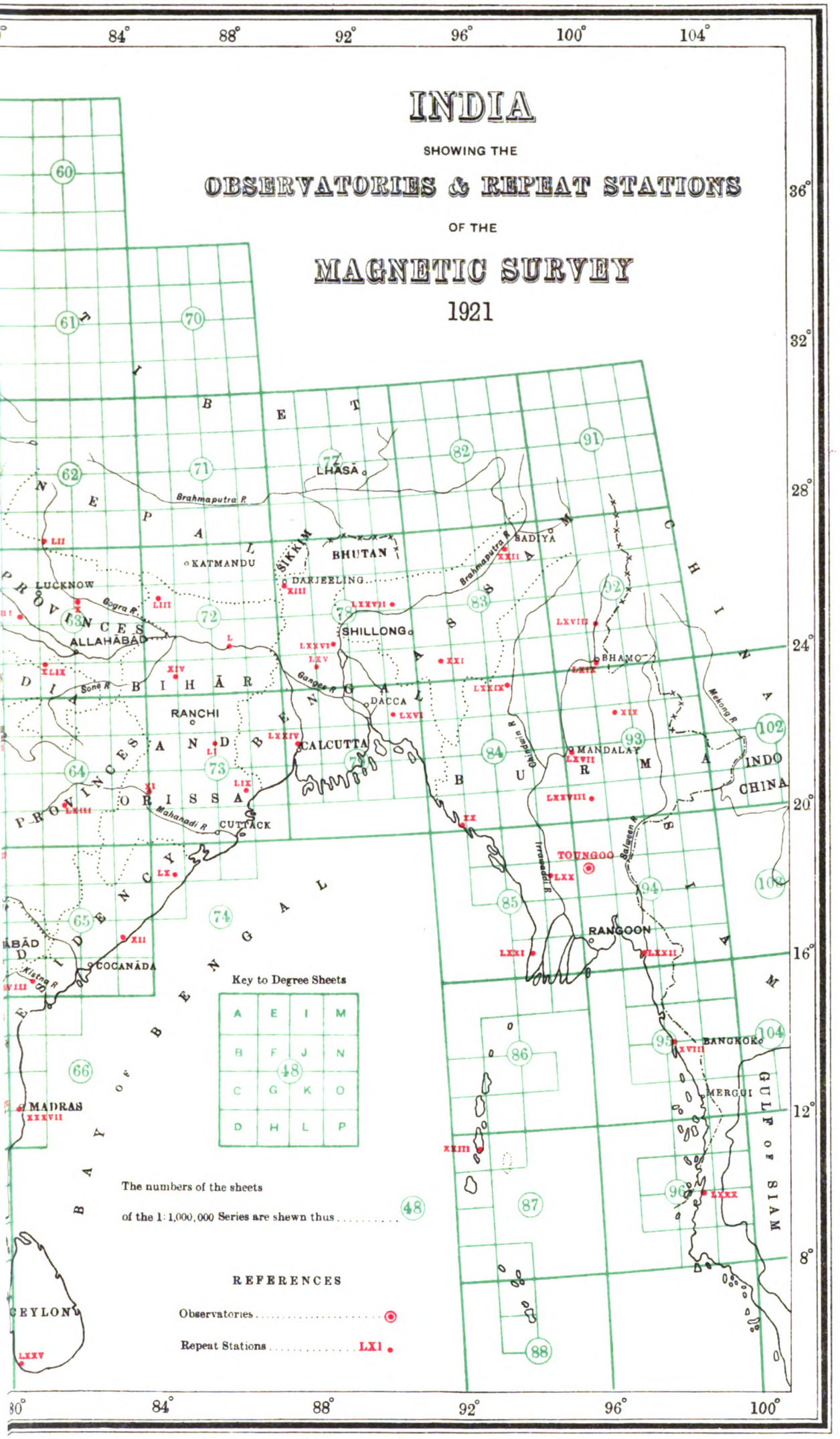

1013 Inches to 240 Miles.

Heliozincographed at the Survey of India Offices, Dehra Dun

100 300 400 500 Miles

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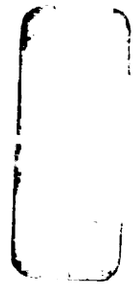

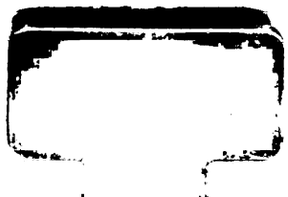

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